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Telescience Testbed Pilot Program Fourth Quarterly Report

*Maria L. Gallagher, ed.
Barry M. Leiner, ed.*

June 1, 1988

Research Institute for Advanced Computer Science
NASA Ames Research Center

RIACS M88.4

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Research Institute for Advanced Computer Science

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The Telescience Testbed Pilot Program is an innovative activity involving fifteen universities in a user-oriented rapid-prototyping testbed to develop the requirements and technologies appropriate to the information system of the Space Station era.

This is the fourth quarterly report, covering the period March 1, 1988 through August 31, 1988.

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1.0 INTRODUCTION

The Telescience Testbed Pilot Program (TTPP) is intended to develop initial recommendations for requirements and design approaches for the information systems of the Space Station era. Multiple scientific experiments are being carried out, each exploiting advanced technologies and technical approaches and each emulating some aspect of Space Station era science. The aggregate results of the program will serve to guide the development of future NASA information systems.

2.0 PROGRAMMATIC SUMMARY

The second meeting of the TTPP participants and interested parties was held 7-9 March 1988 at the University of Colorado, Boulder. This was a highly successful meeting with presentations made by all of the university subcontractors, as well as some related presentations by other organizations. Working sessions were held by each of the discipline areas, in order to coordinate their activities. Demonstrations of a number of activities were given, particularly those involved in workstation and networking applications. Copies of the vignettes may be obtained by contacting Lorraine Fisher at RIACS (llf@riacs.edu).

A contract extension for the RIACS/USRA portion of the TTPP was approved to 31 December 1988. All of the university subcontracts were then extended to 31 October 1988. This will allow each of the universities to complete the initial phases of their experiments and for the results to be integrated into an overall final report.

Significant efforts have been expended by USRA and others in supporting NASA planning for the development of the appropriate information system for science in the Space Station era. This planning activity is continuing.

3.0 TECHNICAL SUMMARY

The TTPP is based on a concept evaluation methodology using a user-oriented rapid-prototyping testbed environment. State-of-the-art technologies and concepts are prototyped for the purpose of evaluating those concepts in a realistic setting. The aim is to evaluate requirements and concepts, as opposed to hardware and software implementations. The environment is user-oriented, meaning that the focus is on the role of such technologies in supporting evolving modes of scientific research. It is not a single testbed, but rather multiple experiments, each emulative of science in the Space Station era.

During the past quarter, significant progress has been made towards the goals of the TTPP. The university activities are beginning to yield results, as evidenced by the presentations at

the meeting held March 7-9. The Area Coordinators for each of the scientific disciplines (Technology, Earth Systems Science, Microgravity Sciences, Astronomy and Astrophysics, and Life Sciences) have each been working with their respective colleagues in those disciplines to articulate the unique requirements of that discipline with respect to future information system requirements. Following up on the previous quarter's activities, the various university testbedding subcontracts have focused on such unique requirements.

In addition, technology efforts underlying the various discipline activities have moved forward. The USRA effort to develop a common Telescience Workstation Environment (TeleWEn) has resulted in an initial release of the environment, which has been distributed to all interested parties. All sites now (or shortly will) have connection to the NASA Science Internet, thus facilitating communications and information exchange.

In Section 4, summaries of the activities are given for each of the science disciplines, prepared by the Area Coordinators. This is followed in Section 5 by the quarterly reports by each of the university subcontractors. Results are beginning to surface from the various testbed activities, some of which are written up in the area and subcontractor reports. In particular, the reports by University of Colorado and University of Arizona have initial discussions of lessons learned. The effects of networking on the Astronomy and Astrophysics community are discussed in that area report (and also in the last quarterly report.)

No significant problems have been encountered in completing this effort.

4.0 AREA QUARTERLY REPORTS

4.1 EARTH SCIENCES - Jeff Star

The TTPP-ES group consists of:

- Purdue University
- University of California, Santa Barbara
- University of Colorado
- University of Michigan
- University of Wisconsin

We continue to work on the problems and opportunities of telescience by considering an integrated field experiment. The scientific rationale behind the field experiment is to examine a specified test site on the earth's surface, from the viewpoint of interface between vegetation and biogeochemistry. The near-term goal of this field experiment is to exercise the telescience concept, to see what capabilities are truly required that are not now available. Based on discussions with the team, the proposed field experiment is planned for the summer, and may involve more than a single field site.

Following the discussions described in the last quarterly report to identify a specific set of science objectives for the field campaign, the Earth Sciences group met at Boulder on March 9, 1988. The general research topic, as a focus for the field experiments, is vegetation's role in global cycles. The long-term objective was to assist in identifying the types of data sets which will be needed for broad studies of vegetative coverage in global programs, such as the IGBP. The near-term goal was to identify one site and a set of specific tasks which will make a substantive beginning in addressing the long-term objective, and which can be accomplished this summer as a collaborative effort by the current TTPP Earth Sciences participants within the available resources. It was envisioned that some aspects of the four M's (Measurement, Mapping, Monitoring, and Modeling) would be included. There was considerable discussion of potential sites, including:

1. the Oxnard Plain agricultural region (arid but irrigated orchards and truck crops);
2. the Burton Mesa oak woodland; and
3. the Tippacanoe County cultivated croplands and timber.

There were initial discussions of the measurements, data sets, models, etc., which would be needed. Two alternative approaches were discussed:

1. the classical measuring and mapping approach, showing how these data feed into current models; and
2. an emphasis on biomass, examining the correlation between greenness and what is seen on the ground, and tying these variables to current hydrologic, nitrogen cycle, energy, and other models. It was decided to concentrate on the classical measuring and mapping approach.

At the end of the meeting it was decided that the UCSB and Purdue members would provide the primary scientific leadership and content. Colorado/LASP is prepared to provide access to the historical data sets and operational support from the SME instruments to obtain new data, with emphasis on ozone and other data which may be useful in making atmospheric corrections applicable to the other data sets. Colorado (Chase, et al) will be able to provide support in use of the HRPT data. Wisconsin is prepared to provide historical meteorological data by extracting selected portions of the operational satellite data. These would include soundings, cloud cover, rainfall, etc. UCSB is prepared to provide access to their library of LandSat image data and related online databases.

Identifying the science tasks has proven to be difficult. The broadly based and integrated objective described above would demand a substantial amount of inter-laboratory planning and coordination. The problem (and lesson learned) is that it is very difficult for practicing scientists to take the time from their current work which is required, in order to plan and execute a new task on short notice. In recognition of this problem, we have changed our approach. The collaborators are presently defining individual science tasks which are locally oriented. They will, however, continue to work toward the general objectives outlined earlier. Cross-linking arrangements will be made to give each participant the benefits of easy connectivity, which is the hallmark of the telescience testbed project.

4.1.1 Purdue University

The SUN 3/60C has been installed, and connected to the Internet, with a domain name of newton.ecn.purdue.edu. After solving hardware problems, Oracle was installed on the SUN during March.

Also, the LoDown 800 megabyte WORM optical disk arrived during March from Arc Laser Optical Technology (ALOT). The software that came with the system will only allow one to copy an entire volume (floppy disk or disk drive), not a file or folder to the optical disk. Therefore, if the file(s) being copied do not fill the entire disk that they are on, a lot of space is wasted on the optical disk. ALOT is upgrading the software to allow one to copy a file or a folder at a time. They hope to have the new version of the software done in early June.

A prototype of the Spectrometer/Multiband Radiometer Database catalog has been developed using Apple's Hypercard. The prototype was demonstrated at the Telescience meetings in Boulder, Colorado, during early March. The Field Research spectral database catalog "stacks" are available to anyone who would like a copy. The eleven files that define the catalog for the spectral database have been loaded into Oracle on the SUN 3/60. The interface for the user is now being implemented.

During April, we successfully accessed BROWSE via a 9600 baud dialup using the US Robotics modems. The session went much better than any connection we have had via the Internet and, of course, better than the slower dialup speeds.

During May, we received the latest copy of the McIDAS PC software, which requires only a color video monitor for accessing and displaying GOES imagery. The system works well on our IBM PC/AT system.

4.1.2 University of Colorado's OASIS

We have been working with Elaine Hansen and Alain Jouchoux to obtain a copy of OASIS for testing remote control of the Solar Mesosphere Explorer satellite. The system that we are going to install OASIS on is a VAXstation 2000 which arrived in April. However, some of the software for it is missing. As of the end of May, the software still had not arrived from DEC. After the software arrives and is tested, we will obtain a copy of OASIS from the University of Colorado to install on the VAXstation.

4.1.3 University of California, Santa Barbara

The TTPP-ES splinter meeting on 9 March '88, in Boulder was extremely helpful. At this meeting we reviewed our progress towards our respective goals, and discussed our respective interests and preparations for the proposed field experiment. We continue to work with the rest of the team in this regard.

One of the experiments we have attempted involves a 9600BPS dialup line modem, which we

have borrowed from Purdue. In the past, we have been unsuccessful accessing one of VAXen through this modem at speeds above 1200bps. After discussions with the manufacturer, we finally have been able to provide 9600BPS dialup service from our BROWSE testbed to the Purdue team. Based on this experience, we have asked the TTPP to purchase a pair of Trailblazer-compatible modems for our field experiment experience.

Our local science scenarios involve problems of real-time spatial data acquisition and modeling. One of the projects involves numerical models of wildland fire behavior. We have developed a scenario, based on these models, which may be of value in understanding the spread of fire so that the remotely sensed data can provide a useful input to the fire fighting crew. We have had discussions with local Forest Service officials, and they are working on our concept with us.

As reported at the TTPP meeting in Boulder, we are working on a data flow exercise, in which data residing on a several computers is accessed from a remote terminal (which emulates a portable PC in the field), and processing capabilities on several computers is used to help solve the problem. We are using a PC/AT with graphics terminal emulation software at the user end of the chain, and three VAX computers (involving both the VMS and UNIX operating systems). The network connections tested include both dialup and hard-wired access from the PC/AT (1200 and 2400BPS dial, and 9600BPS wired)

We have run several tests to assess the performance and reliability of this data transfer and processing problem. The general flow of information involves:

1. requesting data from a database node (UCSB BROWSE Testbed) transferring an image subscene to an image processing system (MicroVAX ERDAS);
2. transferring data to a statistical processing system (S, running under UNIX on a VAX 750); and
3. transferring results back to the PC/AT for further examination by the user.

The first transfer experiment works, and we are examining several enhancements which:

1. include additional processing nodes;
2. include additional data types; and
3. exercise a scientific scenario which interests the Forest Service.

The second build of the Browse Testbed is now in an alpha-test stage. The principal developments in this area include:

1. a hierarchical vector database structure;
2. better use of graphics;
3. higher effective performance; and
4. a greater array of image data types.

During the next quarter, we anticipate mounting the new software build in a public account, providing a new revision of the user manual to the TTPP-ES team, and encouraging the

team to use and comment on the testbed. We look forward to similar exchanges with the SME database at Colorado and the spectral database at Purdue.

4.1.4 Laboratory for Atmospheric and Space Physics, University of Colorado

The primary objective of this task is to establish and exercise a capability so that others may access the LASP SME data, and for us to access their databases. The SME MENU system is on-line and available for use. A preliminary set of documents for guiding other consortium users is available, and will be distributed in the next few weeks. This material will be reorganized and prepared in the form of an integrated final users guide during the coming quarter.

Preliminary information on the use of the UCSB BROWSE system was received earlier from Jeff Star. We believe that we will be capable of working with that system. Arrangements have been made to receive IBM-PC software for working with the McIDAS data received from the University of Wisconsin. That will be put online during the next quarter, and should give us the ability to acquire and use the NOAA operational satellite data.

4.1.5 University of Michigan

The REMOTE COACHING system is steadily improving in its capabilities. Some rules have been found to be incorrect and more video pictures have been needed to make it clearer for the users in the Space Physics lab. The current version of the system is being used for maintenance of an interferometer. However, the final version of the system will provide three modes of operation. The inquiry mode is used by the uninitiated user to learn about the operation of the instrumentation used in the experiment. In maintenance mode, the user is guided through a sequence of steps to perform some maintenance task. The diagnostics mode is used to determine the cause of a failure in the system.

All three modes provide an option to stop the current operation and establish a communication link via modems with the real expert at the local control station (back at the university). After establishing the communication link, the COACHING system at the local site is brought up to a state of operation identical to that of the remote site. The concept of state for the expert system means the activation of the same rule, the same agenda, and the same facts.

Since the modems have not yet arrived, we have not established communication between the remote systems at the Space Physics Laboratory and the local system at the Robotics Lab. However, we have temporarily set up a communications testbed within the laboratory. We are developing the communications software with this testbed while waiting for the modems to arrive. With this testbed system we have solved the problems of capturing a picture at the remote site, compression of the image, transmission to the local site, decompression and display on the SUN video monitor.

4.1.6 University of Wisconsin

Telescience efforts at the University of Wisconsin have resulted in advances in two main areas during the past three months:

1. improvements in IBM PC software designed for the reception; and
2. display of McIDAS data products, and a connection to the Internet.

We have modified our version of IBM PC McIDAS software, such that only a color video monitor is necessary for accessing and displaying GOES visible, IR, and water vapor imagery. The package uses standard asynchronous dialup to access the McIDAS database. The software also includes a scheduling option to allow automatic access of a time sequence of images useful for cloud animation. The software is available upon request to TTPP participants, and has been distributed to Purdue, UCSB, and to the University of Colorado-LASP. We are awaiting feedback from these users.

We recently made connection to the USAN ethernet (NSFnet) in our building, using an IBM AT that will be the foundation of a McIDAS bridge. Our new host name is "McIDAS.ssec.wisc.edu" and is at IP address 128.116.12.97, at this time. Testing of email operations, using the USAN connection, has revealed a number of reliability problems. We suspect that the problem lies in the mail relay host, and are continuing to work the problem.

4.2 LIFE SCIENCES - Larry Young

The Life Science Telescience users, represented by researchers from ARC, JSC, KSC and MIT, produced an overview of the special requirements of the Life Sciences Community for Telescience for presentation to NASA Headquarters representatives. The most immediate output was the "Life Sciences Advocacy Report" issued in May 1988. As interest in the Telescience community increases, particularly among the international partners in Space Station, the need to work on requirements and standardization of everything from video formats to data streams is becoming apparent to all.

The major direct progress on the Life Sciences portion of the TTPP was the completion of the video link from KSC to MIT, the training of the astronaut surrogate and sled operation team at KSC by the MIT investigators, and the preparation for running the formal testbedding experiments during June and July.

4.3 MICROGRAVITY SCIENCES - Dick Hahn

Rensselaer Polytechnic Institute is concentrating in the area of microgravity materials science with the cooperation of the Microgravity Materials Science Laboratory at Lewis Research Center. Efforts this period were directed toward the finalization of the necessary communications/control hardware, experimental equipment and coding of the necessary software. Significant progress has been achieved in these areas and we plan to attempt

remote control at MMSL during the next quarter.

The University of Arizona has made good progress with development of a remote fluid handling the testbed in support of the microgravity and life sciences. Design of the software for the man/machine interfaces has been finalized. Coding and testing of the software is underway, and should be completed by next month. Necessary modifications to the electrophoresis and pH instruments were also finished, and evaluation of the three alternate injection mechanisms is well underway. It is anticipated that the phase one testbed will be completed and demonstrations scheduled by the end of the next quarter.

4.4 ASTRONOMY AND ASTROPHYSICS - David Koch

The first table presents a summary of the network connections that the individual investigators are using. In some cases, not all of the connections for a person's institution are shown, since they may not be utilizing every network for their TTPP activities or may not have access, even though the network does exist on campus. Current connections are shown with a C and future connections are shown with an F.

The bottom line from the experience of the astronomy PIs is that for email, the networks are adequate, but for most other functions they are woefully inadequate. Specifically, the measured transfer rate for files is typically on the order of a kilobyte per second. Commonly available modems are an order of magnitude faster and for this reason, as can be seen from Table 2, most PIs have and use faster modems for this purpose. Unfortunately, it will probably always be true that the users will fill the available network capacity, whatever it is. The situation is somewhat better for performing remote logins. On SPAN, it seems to be fairly good. Not only is it possible to have good connectivity within the U.S., but also to computers that are on SPAN in Europe. However, on the other national networks the reliability is poor, both in terms of getting access and in having a sufficiently long connect time without getting dropped, that is for a fraction of an hour to several hours. Hopefully, for TTPP users this will improve with NSN providing TCP/IP for non-DEC machines. At present no network seems to be adequate for realtime instrument control. But it is too much to expect to have remote real time control, unless it is absolutely necessary for human intervention for performance of the experiment, which is unlikely in astrophysics, but not unlikely in life sciences, material processing, etc. For near realtime control, NSN or SPAN may be sufficient if the reliability can be insured at a 95% or so level for all time and that it is 99.5% reliable for some part of any five minute interval, that is, in any five minute interval one should have connectivity for some portion of the five minutes. At present, the non-NASA national networks do not provide the needed reliability. In addition, for control which requires visual feedback, even with slow scan TV, the bandwidths are not adequate. In general, one would build the instrument controller at the instrument and use the network only for passing instructions to the controller and receiving housekeeping feed back from the instrument, that is, the traditional approach used to run any spaceflight experiment. Rarely is there a need in astrophysics for realtime response by the observer.

NETWORK CONNECTIONS USED BY TTPP

	NATIONAL:						REGIONAL:
	ARPA	SPAN	NSN	BITNET	UUCP	PSDN	
Ames	C	C					C-BARRnet
AZ, Astro.	C		F	C			C-56K to JVNCC F Westnet
AZ, Eng.		C	F	C			C-56K to JVNCC F Westnet
UCB	C	G			C		C-BARRnet
U of Colo.	C	C-56K		C		C	C-56K? to JVNCC
Cornell	C			C			C-NYSERnet C-T1 to JVNCC
U of MD	C	G*		C			None
MIT	C						C-T1 to JVNCC C-Athena
SAO	C	C-56K	C-56K	C	C		C-T1 to JVNCC

Legend ARPA - Actual includes ARPA, NSF, NSI and MILNET
all on Internet, all TCP/IP
SPAN - NASA's DECnet
NSN - NASA's TCP/IP
C - Current connection
F - Future connection
G - Gateway through another site
* - Still requires SPAN from USGS to Lowell Observatory
JVNCC - John Von Neuman Computer Center
T1 - is 1.4 MHz

TABLE 1.

The speeds for the networks other than SPAN and NSN are not shown, since no user can realize a significant fraction of the network bandwidth, whereas, on SPAN, NSN and regional network a substantial fraction of the bandwidth can be realized for short periods of time. An interesting observation is that many of the astronomy PIs have a high speed connection to JVNCC, however, this connection is intended for JVNCC access, not to network remote users to each other.

DIALUP/DEDICATED CONNECTIONS			
	DIALUP	DEDICATED	FUTURE
Ames	9600: general access		
AZ, Astro.	17K: UA to Kitt Peak 9600: data acquisition UA to IPAC database		
AZ, Eng.	9600: UA to Thaw for telescope control	Campus video: visual feedback of remote fluid experiments	
UC Berkeley	1200/2400: login file transfer		9600 dialup or direct: instrument control
U of Colorado	2400: telescope control slow scan video	Campus video: CCD data transfer	Satellite: telescope control
Cornell			
U of Maryland			
MIT	2400: telescope control		17K & T1 potential: campus to telescope CCD data transfer
SAO	2400; general access IR image transfer	T1 UA/Mt. Hopkins: s/w maintenance	

TABLE 2.

Many of the PIs have installed either high speed dialup modems or have a dedicated link for performing some of their activities. These connections are identified in Table 2.

NATIONAL NETWORK USAGE			
	EMAIL	FILE TRANSFER	REMOTE LOGIN
Ames	few kB per day	occasional	occasional
AZ Astro	few kB per day		
AZ Engr	few kB per day	occasional	occasional
UC Berkeley	few kB per day	several MB several times per week	
U Colorado	few kB per day		
Cornell	few kB per day	gave up on trying routine transfer of large files	
U Maryland	few kB per day		
MIT	quite frequently each day	less than 5MB per day	occasional
SAO	tens of kB per day	occasional	continually for remote software maintenance and development

TABLE 3.

These dialup or dedicated links are used for one of two reasons, either to go where no network has gone before or because the existing network capabilities are inadequate. More about this later.

By now, each of the PIs has gained some experience in use of the networks in some way or another. All of them have made use of electronic mail (email) simply by virtue of participating in the TTPP. The use of email has been both via dialup and via the network. NASAmail (a subset of Telemail) can be used both ways. The mail facility, as part of Unix or VMS, makes use of the network. The networks are also being used to perform the TTPP objectives. The usage is shown in Table 3.

NATIONAL NETWORK PERFORMANCE				
	EMAIL	FILE TRANSFER	REMOTE LOGIN	INSTRUMENT CONTROL
Internet	Good	Inadequate: Rate too low for large files.	Marginal: Drop connect	Inadequate: Unreliable Latency too long
SPAN	Good	Inadequate: Rate too low for large files.	Good	Inadequate: Unreliable Latency too long
Bitnet	Good	Inadequate: Rate too low	Marginal: Drop connect	Inadequate: Unreliable

Note: NSN not installed widely enough to have any performance results. Typical transfer rates are 1kbaud on national networks. Regional or campus networks are not included, since in general they have T1 bandwidth and are good or adequate for nearly all purposes.

TABLE 4.

The usage shown may be slightly biased, since after attempting to perform a function several times over the network with constant failure, the user probably has given up and tried an alternate approach.

The results from the network usage are shown in Table 4. Accurate quantitative measures of performance are generally not available and would require many controlled experiments. Those types of studies are better left to computer scientists. Rather, the performance is based more on a qualitative measure of whether the network served as a beneficial resource or a stumbling block based on the types of scientific activities that are performed on a day-to-day basis.

All in all, the biggest difficulty is that the network bandwidth is too low and unreliable to perform most of the science functions envisioned. Recall that one of the major objectives of the overall TTPP was to determine the network communications requirements for performing telescience in the Space Station era. A big plus for all of the PIs is that they have all become use to using the networks for email and the exchange of information with each over the network. This has definitely improved the individuals productivity. This summary should provide a good foundation for evaluating the capabilities of the current networks for performing telescience and for providing a basis for the definition of requirements for the future.

Recommendations (Wish List)

Based on the TTPP experiences to date, the following wish list of recommendations is provided to help to improve the capabilities for telescience in the Space Station era:

1. **Increased reliability and bandwidth:** to be included with NSF backbone at T1 but still inadequate for interactive image processing or other functions requiring high realtime bandwidth such as interactive realtime instrument operations. Bulk data distribution will continue to be done on hard media.

2. **Good directory of addresses/universal mailer:** very often one wants to use email but has no way of determining the correct address. An intelligent mailer that could find people, much like AT&T directory assistance (given a site and a person's name, find his email address) would be helpful.

3. **Routing:** although a site may be connected via a network the local routing controls the link to the next site, ways of determining and defining the Internet route should be available to the user.

4.5 TECHNOLOGY - Barry Leiner

The TTPP involves the use of advanced technology and its role in supporting future scientific requirements. The above sections summarize the various subcontracts from the perspectives of the space science disciplines. However, some of the explorations provide more general functions and are best viewed as underlying technology. In this section, a summary of these activities is provided.

4.5.1 Networking and Communications

As reported last quarter, network performance continues to be of major concern. The report of the Astronomy and Astrophysics community above well illustrates the issue. While the current networks are capable of providing adequate performance when lightly loaded, the usage of the general purpose networks (such as NSI) is high and increasing. Significant planning and engineering effort must be initiated to assure that the needed network

performance will be available.

It should be noted that, at the recommendation of the White House OSTP, the Federal research agencies (DARPA, NSF, NASA, HHS, and DoE) have joined forces to aggressively pursue the evolution of networking to multi-megabit rates and well beyond. (NSF and DARPA are pursuing an initiative to develop gigabit speed networks). This activity is expected to significantly alleviate the bottlenecks currently being experienced by the science community.

Details of networking experiments may be found in the reports of Section 5. We plan to summarize these results in the contract final report.

4.5.2 Workstations

University of California, Berkeley demonstrated the remote commanding of an EUVE prototype instrument at Berkeley from a workstation at the TPP meeting at Boulder using the NSI. This was augmented by compressed video transmission to allow video monitoring of the instrument.

Tests of a WORM optical disk drive at Purdue University have indicated a problem with the file copying software; that the software only allows copying of an entire volume rather than per file or folder. Enhanced software is expected to be released in early June.

Stanford is exploring the use of TAE for workstation monitoring and control of spacecraft. A demonstration instrument interface based on TAE was received from GSFC and brought up on a Sun 3/260.

4.5.3 Software Environments

The TAE Plus (Transportable Applications Executive plus X-Windows) is being explored by the University of Arizona as a development package for building a user interface for a SIRT observer.

The University of California, Berkeley, has determined that a new product by Sun Microsystems (Network Software Environment) is related to the Berkeley Software Control System effort. However, it appears that NSE will not provide the required support for collaboration by distributed groups. Berkeley is investigating how their efforts in this area can be applied to NSE.

4.5.4 Teleoperations

The University of Arizona, Astronomy has had some moderate success in transferring image data from an infrared array camera using 9600 bps modems over telephone lines to support quick look analysis at a remote site.

The University of Arizona, Engineering and Mines has been investigating remote operations

for fluid handling and has considered a number of maintenance issues and testing procedures for failure modes.

The University of Colorado, LASP efforts on OASIS have continued. Porting of OASIS to a Sun environment has been initiated. Coding of a prototype of an OMS has been completed and testing is to begin shortly.

The University of Arizona, Engineering and Mines has continued its investigation of the use of OASIS for teleoperations and the role of the user interface and CCSDS communications protocols. Recent work focussed on the multiple session problem, where non-controlling remote sites can view data.

The University of Michigan is continuing its experimentation with remote coaching. The system is being enhanced and validated simultaneously using the rapid-prototyping user-oriented testbed approach, working with users in the Space Physics Lab.

4.5.5 Teleanalysis

University of California, Santa Barbara, has been investigating data flow in a distributed environment, using a remote terminal to access data residing on several computers. They have been investigating operation at multiple interconnect speeds.

The BROWSE testbed at University of California, Santa Barbara is now in the alpha-test of its second build. This second build represents a number of technical improvements. Tests are planned using data from SME/Colorado and the spectral database at Purdue.

The University of Rhode Island has discovered that the simple image compression strategy of just sampling to send quick look data appears to work quite effectively.

5.0 SUBCONTRACTOR QUARTERLY REPORTS

5.1 UNIVERSITY OF ARIZONA, ASTRONOMY

Institution: University of Arizona (Steward Observatory)

Principal Investigator: Dr. Erick T. Young, Fourth Quarterly Report prepared by Irene Barg

Network Connections: Internet, BITNET, SPAN

Email Address: eyoung@solpl.as.arizona.edu

Telescience Workstation: Sun3/160C, 141 Mb hard disk, 1/4 inch tape drive, sharing hardware and software resources with a MicroVAX II and a Sun 3/150C within the infrared

group. The workstation is connected to the Steward network, which gives us access to the campus network.

Operating system: Sun UNIX (V 3.5)

5.1.1 Hardware Status

Workstation

The telescience Sun 3/160 experienced sporadic re-booting problems the past several months. After much testing, installation of a replacement CPU board solved the problem. We continue to share hardware resources within the infrared group at Steward. Via the Steward network, we mount the IRAF package which resides on a Sun 3/150 and most image files are stored on the MicroVAX II. Even with this sharing of resources between computers, the Mb hard disk is too restrictive for loading and testing the various available software (i.e., TeleWEn and TAE Plus). Now that the workstation has stabilized, we plan to purchase a Mb hard disk to relieve the disk space crunch.

Modems

The three U.S. Robotics Courier HST 9600 bps modems have been used for two functions:

1. transfer of raw data from the Steward HgCdTe array camera from Kitt Peak to a computer on campus for "quick-look" processing. The data rates available with the 9600 baud modems over commercial telephone lines are adequate for this task; and
2. remote access to the IPAC database. The modem connection to IPAC even at rates below 9600 baud have become more desirable than utilizing the existing networks (see Communications Status for more information).

5.1.2 Software Status

The IRAF package is currently mounted on the telescience workstation from another Sun computer within the infrared group. IRAF has been used for image display and other statistical analysis of the raw data produced from the Steward Observatory HgCdTe array camera. Format conversion to FITS for archiving the raw camera data is performed before file transfer takes place.

The TAE Plus Prototype Version 3.0 was installed on the telescience workstation along with X-windows. TAE Plus is currently being evaluated as a development package for building a user interface for a hypothetical SIRTf observer. Concepts being investigated are:

1. status of the remote observing facility;
2. scheduling of remote observation requests;
3. expert systems to provide assistance to the observer in developing an observation request;

4. the ability to do graphical "quick-look" analysis of raw data after an observation run; and
5. access to archived data.

5.1.3 Communications Status

The telescience workstation is connected, via the campus network, to the Internet and BITNET, and is soon to be connected to NSI and WESTNET. Communication experiments with the Cornell TTPP group and IPAC had different results. Network connections from Arizona to the West Coast Region (i.e., to IPAC or Berkeley) are more difficult than network connections to the East Coast Region (i.e., to Cornell or Columbia). It is believed this is due to routing. A transmission to IPAC goes through Arizona's JVNC gateway (a satellite link to the Princeton Supercomputer Network) then rerouted to its destination. This makes interactive use of the IPAC computers painful. Subsequently, the 9600 bps modems were put in place for communications between IPAC and Arizona.

Network communication experiments with the Cornell TTPP group have been more successful. File transfer, using FTP, for files less than 100K work well, and interactive use, using telenet between computers is adequate. File transfer of files larger than 100k become unreliable, and most of the time impossible. (See Cornell's TTPP April Monthly Report for file transfer rates between Cornell and Arizona).

5.1.4 Continued and Planned Activities

Remote Observing

For most astronomers, telescience will not mean teleoperations of a remote instrument. One value of telescience concepts will be in the ability to remotely request and plan observations, check on mission status, receive processed data products, and gain general access to and share astronomical data. The Space Telescope Science Institute has implemented the Remote Proposal Submission System which allows submission over the telenet packet switched network. As mentioned earlier, using the TAE Plus package, we plan to build a user interface for a hypothetical SIRTf observer. Concepts to be investigated are remote observation request, review, scheduling, and the dissemination of the data.

Remote Operation of an Infrared Array Camera

One of the goals of the first year was to investigate the transfer of image data from an infrared array camera to a remote site for quick-look reduction analysis. We have had moderate success using 9600 bps modems over telephone lines. Additional control functions are needed to approach true remote operation of the camera.

Once completely ported to the Sun, the OASIS package may be installed on the current telescience workstation, pending additional hardware and software requirements.

5.2 UNIVERSITY OF ARIZONA, ENGINEERING AND MINES

5.2.1 Programmatic Summary

This is the Spring quarterly report for the astrometric telescope, remote fluid handling, and technology development projects at the University of Arizona. It does not include the University of Arizona involvement in the SIRTf project.

Telescience research can be split into two main areas:

1. remote control, sensing, manipulation, etc.; and
2. remote data storage, retrieval, etc.

The goals of our two telescience testbeds are related to area one above. The first testbed involves teleoperation of the Thaw astrometric telescope, which is a forerunner of the Astrometric Telescope Facility (ATF) to be attached to Space Station. The second involves development of systems and software for Remote Fluid Handling (RFH) in support of the microgravity and life sciences. These seemingly quite different testbed demonstrations were selected to pursue the following goals in our research:

1. design of a set of modular tools to allow teleoperation of scientific experiments. These tools include the man/machine interface at the remote commanding computer and the machine/machine interface between the remote commanding computer and local controlling computer.
2. generic design of these tools so that they are easily applied to various Space Station experiments that scientists will control from their home research sites.
3. evaluation of time delay effects on teleoperations over packet switched computer networks using the NASA Science Internet (NSI) as an example. These results will then be extrapolated to include uplink and relay satellite delays.

The attainment of our first two goals can be measured through the usefulness and similarity of the tools resulting for the two distinct testbeds. The attainment of our third goal will be accomplished by quantitative and qualitative means when the NSI connections become available.

Several maintenance issues have also been considered:

1. ATF testbed: calibration sequences and other self-test sequences for ensuring the proper operation of the instrument.
2. AFT testbed: emergency procedure in case of external interrupts, e.g., the approach of a shuttle (the telescope must be closed).

3. **ATF testbed:** remote login for software maintenance.
4. **RFH testbed:** calibration sequences and other self-test sequences for ensuring the proper operation of the robot.
5. **RFH testbed:** replacement of instruments in the rack by shuttle crew. This is necessary since some instruments will be specific to a particular experiment and will not remain in space for the entire life cycle, and since other instruments may be replaced by newer versions.
6. **RFH testbed:** uploading of new software modules, and installation in the local control computer from a remote location, remote login and editing; and software self-tests.

The following failure mode testing procedures have been developed:

1. **ATF testbed:** failure modes are investigated by simulating randomly occurring failures at the experiment site, while an operator is teleoperating the experiment from the remote commanding computer. This failure analysis is an intrinsic part of the Thaw telescope simulator.
2. **RFH testbed:** no special provisions are necessary. Failures occur naturally, i.e., a syringe rolling off the table, or the HERO robot trying to commit suicide during a power outage (!) Such failures are being handled by teleoperations whenever they occur and provisions are foreseen to prevent repetition (if possible).

5.2.2 Astrometric Telescope (Astronomy and Astrophysics)

Good progress has been made on the astrometric telescope testbed since the last report. The major results that were obtained are:

1. The design of the user interface for the remote telescope control testbed has been completed (senior project report of Steve Gates). A preliminary working paper can be made available to interested parties now, and a final version will be available as a TSL report shortly.
2. The coding of the new Oasis application database for the remote telescope control has been completed including all menu items, command functions and display windows.
3. Not yet completed are the communication interface using the CCSDS protocol, the handling of incoming textual information, and the handling of incoming bitmaps for display in an Oasis display window. Also not completed, is the mapping of incoming finderscope and guiderscope data into appropriate display windows. This will be our primary activity during June.
4. Basically, the Thaw telescope simulator has been completed. All commands are now correctly scanned, parsed, and processed.

5. We are currently working on a failure simulator. The idea is as follows: we will use a random number generator to draw uniformly distributed random numbers between 0 and 1. For each incoming command, we will draw one random number, and compare it with a threshold (e.g., 0.9) that can be user specified. If the drawn number is above the threshold, the command will be processed incorrectly (e.g., it will be processed correctly, but the acknowledgment message is never sent back, or an acknowledgment message is sent back, but the command has not been properly processed, etc.) We want to use this failure simulator for training purposes. A remote experiment commander who is not familiar with the details of the simulated failure modes will have to figure out what went wrong, and will have to think of a way to fix the problem. A side effect of this failure simulator will be that we will be able to learn which types of problems can be fixed with the current user interface, and where we still need to augment the user interface.

6. We are also still working on a complete set of safety checks. The local controlling computer will have to scrutinize each incoming command to see whether it is potentially harmful. Some checks have already been built into the simulator, but this is still an ongoing development.

Additional details on these items are contained in the technology section (5.2.4) of this report.

5.2.3 Remote Fluid Handling (Microgravity and Life Sciences)

Software Issues

The design of the man/machine interface for the remote fluid handling laboratory has been completed. The interface is primarily menu driven and is simple enough that a novice user can operate the laboratory, but it is also detailed enough to take advantage of all the laboratory functions. This work has been documented and is available as technical report TSL-009/88.

The machine/machine interface design has also been completed. It includes communication between the remote command computer and the local control computer for enabling data transfer, controlling the robot, and interacting with the various instruments in the laboratory. This is documented in technical report TSL-006/88.

A draft of the computer/instrument interface for the remote fluid handling laboratory has also been completed. The document does not list the exact commands and programs which will constitute the interface, since these will need to be changed as the equipment changes. However, it does give a description of the required functions of the commands and programs which will operate the equipment of the laboratory. This draft is available as TSL-010/88.

The Meridian ADA compiler and software package was received, installed, and tested on our PC/XT compatible. The tests consisted of the sample programs which were provided with the package, and all eventually passed. There was one problem detected with the test

program for the math library, but after calling the software support line, it was resolved. Evidently for 8086 processors, a parameter is required when linking programs which use the math library. Another problem was detected by Ames Research Center concerning low level I/O, but this problem has also been resolved. The ADA compiler will be used frequently in the next month for the implementation of the local control protocols for the remote fluid handling laboratory, and a more detailed review of the software will be available at that time.

System/Hardware Issues

In any microgravity environment, fluids must be handled in closed containers under pressure, with special attention paid to the avoidance of air-liquid interfaces. This technique has been demonstrated using remote robot control of an apparatus in which fluid was transferred by use of a syringe. The Scorbot robot arm has proven to be sufficiently accurate to introduce specially designed syringes into their also specially designed receptacles for remote fluid handling. Double containment is being used anywhere. The syringe can be used to penetrate a septum to withdraw a fluid from a plastic collapsible bag, where the bag is contained in a standard test tube.

Operation of the syringe adapter for fluid handling by the Scorbot has indicated the need for incorporating safeguards against breakage of needles. The problem will be more pronounced when the operator is in the robot control loop. Then, inaccuracies in positioning the end-effector may result in misalignment of the syringe adapter with the hole in the fixture. Two possible solutions are:

1. an end-effector equipped with a force sensor that will detect excessive force of contact and signal the robot to discard the syringe with the damaged needle; or
2. coordinated control of a vision system and the robot, to detect and correct misalignments before the needle comes in contact with the fixture.

Our recently acquired vision system (obtained from separate funds), which was not available to the telepresence project until now, will provide us with the opportunity to experiment with the latter solution.

As an alternative to the inhouse-designed syringe driver assembly, a battery-operated motorized pipette, recently introduced to the market by the Rainin Instrument Co., was ordered and has been received. This pipette uses disposable tips and is equipped with a mechanical tip ejector. This feature is one of the advantages of the pipette over the syringe assembly, where a contaminated syringe must be disposed of rather than the tip. Also, the digital pipette lends itself well to direct computer control of the fluid volume in the tip and simplifies the robotic tasks. It is hoped that the use of this device will eliminate the need for the syringe holder and fixture, will be more in line with the current industry trend towards fixtureless assembly, and will reduce the overall weight of the components used in the system. Since this pipette has been designed for use in ground-based laboratory work, and picks up fluids by creating a vacuum in a chamber above the disposable tip, changes will be necessary to prevent the fluid from floating up this chamber in reduced gravity. The current

thinking calls for using syringes with needles rather than the provided plastic tips, where each syringe will be fitted with a plastic membrane attached to the spring. Then, fluid pressure will push the membrane up in the syringe barrel and with enough surface tension no fluid will escape the sides of the membrane.

A major modification to the electrophoresis instrument was needed in order to adapt the needle guide on the inlet ports of the instrument to conform to the accuracy of the robot. A tapered needle guide will provide the robot with sufficient flexibility during injection of samples into the capillary tube. The flow-through pH-meter to be used in the demonstration will be fitted with a solenoid valve at its outlet. Then, rinsing of the capillary tube is possible by sending an appropriate signal from the controlling PC to shut off or open the valve.

Two of the available five timer/counters on the LabTender board have been used to trigger two of the available A/D channels, at desired times, under software control. For the electrophoresis device, a sampling period of one second is sufficiently fast, considering the slow time response. The counters can be used to provide sampling rates of up to 100 Hz. Since the pH-meter being used is a flow-through type, taking the average of a few (3-5) pH readings after injection of a sample provides a reasonably accurate pH value. Online calibration of the instruments may also be needed, if signal drifting becomes noticeable.

Future Plans

During the TTPP II meeting held at Boulder, Colorado (March 7-9, 1988), several of the participants associated with NASA's Ames Research Center (John Bosley, Vicki Johnson, Arshad Mian, Daryl Rasmussen, and Chris Vogelsong) met with a number of participants from the University of Arizona (Francois Cellier, Larry Schooley, and Don Schultz) to discuss topics of mutual interest. In particular, it was discussed whether and how far a cooperation between these two groups should and could proceed.

It was concluded that a cooperation between the two groups on a number of different topics seems highly profitable to both groups. Such topics include:

1. remote robot control;
2. fluid handling for the life sciences testbed;
3. OASIS application development;
4. man/machine interface;
5. machine/machine interface;
6. machine/machine communication protocol; and
7. simulation.

It was agreed that the University of Arizona will provide help to NASA for reproduction of part of the testbed environment that has been developed at the University of Arizona. This includes, in particular, the special syringes and syringe receptacles. These will be built by the University of Arizona for NASA. NASA may also decide to buy a SCORBOT robot and use it instead of the HERO 2000 for their experiment. This would allow AMES to also copy

our robot control software.

In order to intensify the information exchange between the two groups, the following provisions will be made: a graduate student at the University of Arizona (Jerry Hunter) has worked full time during the months of April and May 1988 in the University of Arizona TTPP project. His senior project was also in this laboratory (instrument rack design) and he has acquired detailed knowledge about our remote fluid handling testbed (in particular, the hardware/software configuration of the robot control environment, and information about the OASIS databases). He will work during the months of June and July 1988 in Daryl Rasmussen's group at AMES to transfer the previously acquired knowledge to AMES, and to pick up new knowledge from AMES. He will then return to Arizona for the fall semester to bring his newly acquired knowledge back into Arizona's TTPP project.

Another meeting was held at the University of Arizona on March 24 and 25, to follow up on these discussions. Those participating were Vicki Johnson from RIACS, and Chris Vogelsong from Bionetics (both representing Daryl Rasmussen of NASA Ames Research Center), as well as, Larry Schooley, Francois Cellier, Don Schultz, Dick Mosher, Richard Bienz, Yadung Pan, Reza Fardid, Byron Hack, Alfie Lew, and Julie Willis from the University of Arizona.

After extensive tours of the University of Arizona telescience project facilities and demonstrations of the major accomplishments, the meeting ended with a general discussion and summary. It was concluded that the agreements of the previous meeting had been reinforced, and that a cooperation between the two groups on the topics listed above would indeed be highly profitable to both groups.

5.2.4 Technology

By developing two separate and quite different testbeds in parallel, the University of Arizona team has already learned how to modularize the testbed environment in such a manner that a large variety of quite different Space Station applications will be able to profit from the testbedding activities. The results have already shown that the assumptions about hidden similarities between seemingly distinct remote control/sensing activities were indeed correct. These can be identified and utilized in a modularized experimental system design, with minimal change from application to application. It has already become clear how major portions of the technology development can be used in both testbeds.

The man/machine communication interface (using OASIS) can be made sufficiently generic to be applicable to almost any remote control/sensing situation. Differences between various applications can be confined to the development of a new application database.

The machine/machine communication interface (a command language used for the exchange of information among the remote commanding computer and the local controlling computer) can also be made sufficiently generic to be applicable to almost any remote control/sensing situation. Differences between various applications can be confined to the development of new scanner tables which are being automatically generated by a compiler-compiler out of a

user supplied generic data tablet. The communication protocol (using the CCSDS packet telemetry standard) can also be made independent of the application.

Perhaps more importantly, each program module can be decoupled from (i.e., made independent of) the program modules to its left and to its right by appropriate data flow protocols. These protocols are designed in such a way that high-level user commands are successively reduced to sets of lower-level commands, at the expense of a higher data traffic through the communication link.

Lately, we have been working on the multiple session problem, which can be described as follows: while one ground station (e.g. one of the universities) controls an experiment onboard Space Station, the experimenter may need some advice, either from NASA or from some other scientists. Thus, it seems desirable that, while one experimenter controls his experiment, others can observe what is going on. These others can be also groundbased, or they may involve Space Station personnel.

For this purpose, we have introduced a "privilege key," which is maintained by the local controlling computer (onboard Space Station). An experimenter who is not in possession of this key can issue all "SHOW"-commands and "DISPLAY"-commands, but all "SET"-commands are disabled. Since only one key exists which can be assigned to any one of the potential operators, others can observe, but they cannot intervene.

Any observer who has requested and obtained the privilege key automatically becomes the commander of the experiment. The local controlling computer keeps track of the experiment. For each type of experiment, experimental actions will be defined, so that the local controlling computer knows at all times whether an experiment is still ongoing. If an experiment is interrupted, e.g. because the experimenter did not do anything for a predefined timeout period, the local controlling computer will automatically take back the privilege key. The same is true if the connection is lost.. For each type of experiment, a set of emergency procedures will be defined which be executed by the local controlling computer after it forcibly takes back the privilege key (e.g. due to lost connection).

Experiments can also be performed in batch (by using delayed commands). In which case, the local controlling computer becomes the commander of the experiment, and will not sign out the privilege key until "his" experiment is completed. In order to avoid congestion, it is possible for the local controlling computer to maintain a sign-up sheet to reserve experiment time.

There is one disadvantage to be noted for the above outlined procedure. In fact, the local controlling computer becomes a single non-duplicated resource. If the local controlling computer gets confused, and, e.g., is no longer willing to sign out the privilege key, we are stuck. For this reason, an override command will also be made available, which requires the knowledge of a password. This override command will never be used as long as the local controlling computer performs correctly.

There is a need for the different observers and the commander to communicate with each

other. For that purpose, we need a mail facility, and eventually, a phone facility. It will not be feasible to rely on existing facilities as they are available, e.g., for DECnetted VAXes. Instead, we need to map these facilities onto the communication protocol (CCSDS) which will be utilized for the remote control of the experiment.

Currently, this seems to pose a certain problem, since the Oasis software has been equipped to receive telemetry information only. Presently, all incoming data for Oasis must be numerical data. Oasis can issue textual information but is not capable of handling an incoming text. Of course, this problem can be solved by declaring a message to be a mail message (message types can be identified by a number stored in the message header). Inside a mail message, each character can be mapped into an equivalent integer. In this way, mail messages can be encoded into numerical form on the sender side, and can be decoded back into textual form on the receiver end. However, this technique is kind of crude. We suggest that LASP may want to look into this problem.

Since we have two MicroVAX workstations available, we will be able to actually testbed a multiple session environment, and we plan to do so in the case of the remote fluid handling experiment. However, this will require Oasis to run on both workstations. For that purpose, we may have to buy a larger (159 MByte) disk for the second workstation, an expenditure which we had not budgeted for in the first TTPP round. (The second workstation is a tailored down workstation with a small disk which may be unable to host the VMS operating system, Oasis, and the application databases simultaneously.)

The problem reported last month with installing the latest release of the OASIS software has been resolved. The problem was due to a difference between the versions of VMS installed at LASP and the version at the University of Arizona. While LASP had upgraded their VMS to release 4.7, the University of Arizona was still running release 4.6. The latest release of OASIS will not work with a release of VMS older than 4.7. The problem was caused by VMS itself (probably related to the new CCSDS protocols implemented in OASIS), and was not caused by the ADA environment, that is, it is not necessary to upgrade ADA to its newest release for the newest OASIS release to operate correctly.

5.2.5 Future Plans

The initial demonstration projects are on schedule for completion during the next quarter (June-September). After that is accomplished, we shall be concerned with writing the final report, and with submitting proposals for Phase II of the Telescience Program. It is anticipated that this will include further development and enhancement of life science applications, as described above, as well as conversion of the Thaw simulator to a realistic ATF simulator. A complete list of objectives, requirements, and activities to be simulated will be developed as part of this effort.

5.2.6 TSL Publications

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Tucson AZ, February 1987.

2. Y. Pan, Teleoperation of Mechanical Manipulators Aboard the U.S. Space Station, Technical Report TSL-002/87, Electrical and Computer Engineering Department, University of Arizona, Tucson AZ, December 1987.
3. L. C. Schooley and F. Cellier, Telescience Testbed Pilot Program Quarterly Report, Technical Report TSL-003/87, Electrical and Computer Engineering Department, University of Arizona, Tucson AZ, December 1987.
4. F. Cellier, Teleoperation of the Thaw Telescope at the Allegheny Observatory: A Case Study, Technical Report TSL-004/87, Electrical and Computer Engineering Department, University of Arizona, Tucson AZ, December 1987.
5. L. C. Schooley, R.A. Bienz and F. Cellier, Basic Research in Telescience Testbed Program Final Report: NASA Grant NAGW-1073, Technical Report TSL-005/88, Electrical and Computer Engineering Department, University of Arizona, Tucson AZ, January 1988.
6. B. Hack, Machine-to-Machine Interface for a Remote Fluid Handling Laboratory, Technical Report TSL-006/88, Electrical and Computer Engineering Department, University of Arizona, Tucson AZ, March 1988.
7. L. C. Schooley, D.G. Schultz and F. Cellier, University of Arizona Presentation, Second Telescience Testbed Pilot Program Meeting, Technical Report TSL-007/88, Boulder Colorado, March 7-9, 1988.
- 8.. L. C. Schooley and F. E. Cellier, Telescience Testbed Pilot Program Quarterly Report for Winter 1987-1988, Technical Report TSL-008/88, Electrical and Computer Engineering Department, University of Arizona, Tucson AZ, March 1988.
9. B. Hack, Man-to-Machine Interface for a Remote Fluid Handling Laboratory, Technical Report TSL-009/88, Electrical and Computer Engineering Department, University of Arizona, Tucson AZ, April 1988.
10. B. Hack, Computer Instrument Interface for a Remote Fluid Handling Laboratory, Technical Report TSL-010/88, Electrical and Computer Engineering Department, University of Arizona, Tucson AZ, April 1988.
11. E. Raize, Computer Interface for Electrophoresis Apparatus, Technical Report, TSL-011/88, Electrical and Computer Engineering Department, University of Arizona, Tucson AZ, May 1988.
12. E. Raize, Syringe Driver Assembly for Automated Fluid Handling Laboratory, Technical Report, TSL-012/88, Electrical and Computer Engineering Department, University of Arizona, Tucson AZ, May 1988.

5.3 UNIVERSITY OF CALIFORNIA, BERKELEY

5.3.1 General

The majority of the U.C. Berkeley's telescience effort during this quarter centered around preparation for the TTPP II meeting at the Laboratory for Atmospheric and Space Research (LASP) of the University of Colorado, in Boulder. Other work involved enhancing our network connectivity to the world outside the Space Sciences Laboratory (SSL). We have continued to upgrade our software for the remote teleoperation project and the wide area software control system (SCS). Lastly, we are preparing three manuscripts to be published as conference proceedings of two international meetings.

Drs. David Gilman and Gunter Riegler of the Astrophysics division, NASA Headquarters visited our Laboratory in May. We have briefed them on the progress of our telescience efforts and discussed our future plans.

5.3.2 The Boulder Meeting

Four members of our team participated in the meeting. Supriya Chakrabarti, Herman Marshall and Will Marchant presented status report of our activities. George Kaplan gave a brief presentation on IRAF, an image processing and data analysis facility which has seen wide applications, particularly in the astronomical community.

Will Marchant and George Kaplan presented a demonstration of our teleoperation project. It consisted of remote commanding of the Extreme Ultraviolet prototype instrument located at Berkeley from a workstation at LASP, Boulder, via the Internet. We also collected telemetry stream sent by the instrument. The raw telemetry rate was 32 kilobits per second but data compression reduced this considerably for the demonstration since only engineering data was sent. The science data "slots" were all empty. The demonstrations were conducted successfully in spite of numerous periods of network dysfunction. As is usually the case, the network would die and then resume function shortly (too shortly!) before a demo. It is difficult to estimate the actual network throughput attained, but our guess is that we averaged about 4 kilobits per second, with occasional bursts of up to 8 kilobits per second between U.C. Berkeley and Boulder. Data compression and encryption issues were also addressed in this experiment.

Furthermore, a visual feedback of the command and telemetry experiment was provided through video signals sent over the Internet, which demonstrated the results of command executions. Details of the video data handling are described below.

The intervening time has been spent in attempting to increase our understanding of the network environment (and hence, our ability to utilize its scarce resources) and in the work of getting evaluation copies of user interface software for us to try. Our efforts in this area

are described in a later section.

Video Support for Demonstrations at the Boulder Meeting

Our demonstration at the March TTPP meeting in Boulder included visual feedback for our remote commanding operations in the form of low frame rate, limited resolution video images transmitted over the Internet. Originally, we had not planned to do any work with video but we felt the demonstration would be more effective with something more visually appealing to display than engineering status readouts.

In January, we started looking for simple methods of transmitting video images the meeting site in Boulder. We selected the Imagewise video digitizing system made by Micromint Inc. of Vernon, CT. This system has two components. A digitizer/transmitter grabs individual video frames and transmits them over an RS-232 line to a receiver/display unit that converts the data back to NTSC format for display on a monitor. Three different resolutions are provided, and run-length encoding is used for data compression. Operating at 19.2 Kbps, with a resolution of 128 by 122, it is possible to transmit a frame in 10 seconds or less. This is sufficient for our demonstration, allowing viewers to see images of the vacuum box door before and after the commands have been sent.

Some additional software was written to allow us to transmit the video images over the Internet. The Imagewise transmitter sent video frames to one of the workstations in our lab, where a server program performed some additional data compression and transmitted the data to a client at the site of the Boulder meeting. The client software displayed each video frame in a window on the console screen of the color Sun workstation being used for the demonstration.

Prior to the TTPP meeting we were only able to test the video system on our local Ethernet. We were not sure if the Internet would provide enough bandwidth for the demonstration. As it turned out, everything worked, in spite of network problems and a last minute change in the demonstration hardware in Berkeley.

5.3.3 NSI Issues

Those who were able to watch our demo in Boulder know that the performance of the network connection from Boulder to Berkeley was, at best, erratic. It was often difficult to establish a connection. Once established, the connection would run well for a few minutes but then would be lost. Since the TTPP meeting, we have been communicating with Milo Medin at Ames and Cliff Frost on the UCB campus about possible causes and solutions to the network problems. As a result of this discussion, we have learned a few things about NSI (NSN in our case, since we use TCP/IP) which we were unaware of before. Specifically, that being connected to NSN does not imply that you can take full advantage of the NSN:

1. As a NASA-funded site (and a TTPP participant), SSL is entitled to NSN access.
2. For technical reasons, only a single NSN connection is made to the LAN at each

site. In our case, this is through the BARRNET connection to UCB.

3. For technical reasons, SSL network traffic cannot be handled differently from the general UCB traffic.

4. As a matter of policy, UCB traffic is not routed via NSN since UCB as a whole is not a NASA site.

This means that although we can use NSN to communicate with a NASA center such as JPL, we cannot, in general, use NSN to talk to another TTPP participant, such as the University of Colorado. Instead, such traffic is routed via ARPANET or NSFnet, both of which are heavily loaded. Some purely technical solutions may be available:

1. The NSFnet backbone will be converted to T1 this summer. This would have helped in our demonstration but it does not address the general problem of NSN access.

2. We could get an account on a machine at Ames, and log in there in order to access the NSN. This is fine for remote logins or file transfers but is not really acceptable for the custom client-server software we run for our remote commanding.

3. It has been suggested that SSL change its network address to be separate from the UCB network in order to have our network traffic routed differently. This will also require additional communications lines.

We are presently continuing our efforts toward improving our connectivity to NSI. Until recently Marc Siegel at Ames was "99% certain" that the only thing that has to be done is to change the routing information on the UCB campus, together with getting a new network address for SSL. As of late May, however, the network routing hardware on the UCB campus was not capable of supporting separate routing for SSL network traffic. This means that we will need to install a separate link to Ames in order to get access to the NSN lines. Apparently, NSI will not fund such a link since we are already connected via UCB and BARRnet. In coming months, we will be working to resolve the funding and other issues in order to get this matter settled.

Software Control System

Our existing Software Control System (SCS), allows efficient development of software by a group of people. When we developed this system, no commercial product was available. Recently, Sun Microsystems announced such a product, called the Network Software Environment (NSE). The EUVE project will be purchasing Sun's NSE, which performs the same functions as SCS but is more flexible and provides better support for multiple revisions of a software project. It does not, as far as we can tell, provide direct support for collaborations by widely distributed groups. We plan to investigate how the work we have completed on an Extended SCS (with nightly updates of directories shared by two sites, Berkeley and MIT, for example) can be adapted for distributed sites using NSE.

5.3.4 Publications During This Quarter

We have submitted three abstracts for consideration for reporting in two international meetings. All three have been chosen for presentations in October and are listed below. Supriya Chakrabarti was also invited to chair a session at the 14th annual conference of IEEE Industrial Electronic Society (IECON '88):

S. Chakrabarti, W. T. Marchant, C. A. Dobson, G. C. Kaplan, M. L. Lampton, and R. F. Malina, "Remote Command and Telemetry Handling for a Spaceflight Instrument", to appear in the proceedings of IECON'88, 14th Annual Conference of IEEE Industrial Electronics Society, Singapore, 1988.

H.L. Marshall, C.A. Dobson, V. Saba, D. Quinlan, W. T. Marchant, A. Hopkins, G. C. Kaplan, R.F. Malina, S. Chakrabarti and S. Bowyer, "The Use of Simulations for Developing Hardware and Data Analysis Systems", to appear in the proceedings of IECON'88, 14th Annual Conference of IEEE Industrial Electronics Society, Singapore, 1988.

S. Chakrabarti, W. T. Marchant, G. C. Kaplan, C. A. Dobson, M. L. Lampton, and R. F. Malina, "Telescience at the University of California, Berkeley", to appear in the proceedings of XXXIX International Astronautical Congress, Bangalore, India, 1988.

5.3.5 Plans for Next Years' Activities

We have formulated some tentative plans for activities during the next year of TTPP which were sent to Dave Koch, Astronomy Leader. The following is a list of some of the activities we have discussed:

Real-time Teleanalysis

The purpose of this experiment is to exercise and test the teleanalysis capability being developed for EUVE. Members of the Space Astrophysics Group at SSL will be launching a sounding rocket in September of 1988 to make observations of the Sun and terrestrial airglow. We plan to establish a link from the launch site on Wallops Island, VA to the EUVE computer system at SSL in order to obtain telemetry from the rocket instruments in real-time. Software adapted from the EUVE End-to-End System will perform a quick-look analysis of the rocket data (for example, to determine atmospheric temperature or composition). Ideally, results will be produced before the end of the twenty minute data window of the rocket flight.

Teleoperation of EUVE BCE Tests

This activity will focus on remotely operating the EUVE instruments during planned offsite tests using the bench checkout equipment (BCE) computers. Remote operation of the EUVE hardware was demonstrated at the March 1988 TTPP meeting in Boulder, CO, using prototype command, data, and power (CDP) and telescope interface (TIF) units. By establishing high-speed communications channels to the test site in Colorado we will be

able to operate the BCE and the instrument from Berkeley. It should be emphasized that this is not just a demonstration but will be an essential part of the testing process for the EUVE instruments.

Teleoperation of GSFC Simulator

We are working with Code 408 at GSFC to perform teleoperations using their EP spacecraft simulator. This simulator is also used as the last integration step before the EUVE Science payload module is integrated into the real EP spacecraft. During the next year of the TTPP, teleoperation with the simulator alone will provide important tests of our ability to operate with GSFC prior to the final integration tests and flight operations.

5.4 UNIVERSITY OF CALIFORNIA, SANTA BARBARA

We continue to work towards a field experiment in the summer of 1988. The goal of this field experiment is to exercise the telescience concept to see what capabilities are truly required that are not now available. As we have discussed in previous reports, the field experiment, to date, has served very well to focus our attention on both the problems and opportunities we face.

The TTPP-ES splinter meeting on 9 March 1988, in Boulder was extremely helpful. At this meeting we reviewed our progress towards our respective goals and discussed our respective interests and preparations for the proposed field experiment. We continue to work with the rest of the team in this regard.

One of the experiments we have attempted involves a 9600bps dialup line modem, which we have borrowed from Purdue. In the past, we have been unsuccessful in accessing one of VAXen through this modem at speeds above 1200bps. After discussions with the manufacturer, we finally have been able to provide 9600bps dialup service from our BROWSE testbed to the Purdue team. Based on this experience, we have requested that the TTPP purchase a pair of Trailblazer-compatible modems for our field experiment.

Our local science scenarios involve problems of real-time spatial data acquisition and modeling. One of the projects involves numerical models of wildland fire behavior. We have developed a scenario, based on these models, which may be of value in understanding the spread of fire so that the remotely sensed data can provide a useful input to the fire fighting crew. We have had discussions with local Forest Service officials and they are working on our concept with us.

As was reported at the TTPP meeting in Boulder, we are working on a data flow exercise, in which data residing on a several computers is accessed from a remote terminal (which emulates a portable PC in the field), and processing capabilities on several computers is used to help solve the problem. We are using a PC/AT with graphics terminal emulation software at the user end of the chain, and three VAX computers (involving both the VMS

and UNIX operating systems). The network connections tested include both dialup and hard-wired access from the PC/AT (1200 and 2400BPS dial, and 9600BPS wired).

We have run several tests to analyze the performance and reliability of this data transfer and processing problem. The general flow of information involves:

1. requesting data from a database node (UCSB BROWSE Testbed) and transferring an image subscene to an image processing system;
2. (MicroVAX ERDAS)- transferring data to a statistical processing system (S, running under UNIX on a VAX 750); and
3. transferring results back to the PC/AT for further examination by the user.

The first transfer experiment works, and we are examining several enhancements which:

1. include additional processing nodes;
2. include additional data types; and
3. exercise a scientific scenario which interests the Forest Service.

As we become more sophisticated in this effort, we will begin to include our TTPP-ES collaborators as sources of data and processing capabilities.

The second build of the Browse Testbed is now in an alpha-test stage. The principal developments in this area include:

1. a hierarchical vector database structure,;
2. better use of graphics;
3. higher effective performance; and
4. a greater array of image data types.

In the next quarter, we anticipate mounting the new software build onto a public account, providing a new revision of the user manual to the TTPP-ES team, and encouraging the team to use and comment on the testbed. We look forward to similar exchanges with the SME database at Colorado and the spectral database at Purdue.

5.5 UNIVERSITY OF COLORADO, LASP

5.5.1 OASIS Porting to the SUN Workstation

The development SUN workstation still has not been delivered. It is now scheduled for shipment from the factory on June 9. In the meantime, the VERDIX Ada compiler has been installed on a SUN workstation of the CCAR department at C.U. (thanks to Bob Chase), and some of the development has been started.

5.5.2 Operations Management Systems (OMS)/Platform Management

System (PMS) Prototype

The development of the OMS/PMS prototype is progressing well. All coding is complete, and we expect to start testing part of the implementation late in June, with a full system being operational sometime in August. The completed prototype will provide the tools to allow us to address the critical telescience issues of reactive control and transaction management.

5.5.3 Earth System Science

Remote Access to Data for Teleanalysis

The primary objective of this task is to establish and exercise a capability which will make it possible for others of the consortium to access the LASP SME data, and for us to access their databases. The SME MENU system is online and available for use. A preliminary set of documents for guiding other consortium users is available, and will be distributed in the next few weeks. This material will be reorganized and prepared in the form of an integrated final users guide during the coming quarter.

Preliminary information on the use of the UCSB BROWSE system was received earlier from Jeff Star. A first access to that system from Boulder was made during the TTPP workshop in March. Thus, we believe that we have the capability to work with that system.

Arrangements have been made to obtain IBM-PC software for working with the McIDAS data received from the University of Wisconsin. That will be put on-line during the next quarter, and should give us the ability to acquire and use the NOAA operational satellite data.

Telescience Field Campaign

Following the discussions described in the last quarterly report to identify a specific set of science objectives for the field campaign, the Earth Sciences group met at Boulder on March 9, 1988. The general research topic settled upon was the role of vegetation in global cycles. The long-term objective was to assist in identifying the types of data sets which will be needed for broad studies of vegetative coverage in global programs, such as the IGBP. The near-term goal was to identify one site and a set of specific tasks which will make a substantive beginning in addressing the long-term objective, and which can be accomplished this summer as a collaborative effort by the current TTPP Earth Science participants within the available resources.

It was envisioned that some aspects of the four M's (Measurement, Mapping, Monitoring, and Modeling) would be included. There was considerable discussion of potential sites, including:

1. Oxnard Plain agricultural region (arid but irrigated orchards and truck crops),
2. Burton Mesa oak woodland, and

3. Tippacano County cultivated croplands and timber.

There were initial discussions of the measurements, data sets, models, etc., which would be needed. Two alternative approaches were discussed:

1. The classical measuring and mapping approach, showing how these data feed into current models; and
2. An emphasis on biomass greenness, examining the correlation between greenness and what is seen on the ground, and tying these variables to current hydrologic, nitrogen cycle, energy, and other models. It was decided to concentrate on the classical measuring and mapping approach.

At the end of the meeting, it was decided that the UCSB and Purdue members would provide the primary scientific leadership and content. Colorado/LASP is prepared to provide access to the historical data sets and operational support from the SME instruments to obtain new data, with emphasis on ozone and other data which may be useful in making atmospheric corrections applicable to the other data sets. Colorado (Chase, et al) will be able to provide support in use of the HRPT data. Wisconsin is prepared to provide historical meteorological data by extracting selected portions of the operational satellite data. These would include soundings, cloud cover, rainfall, etc. UCSB is prepared to provide access to their library of Land Sat image data and related online databases.

Identifying the science tasks has proven difficult. The broadly based and integrated objective described above would demand a substantial amount of inter-laboratory planning and coordination. The problem (and lesson learned) is that it is very difficult for practicing scientists to take the time from their current work to plan and execute a new task on short notice. In recognition of this problem, we have changed our approach. The collaborators are presently defining individual science tasks which are locally oriented. They will, however, continue to work toward the general objectives outlined earlier. Cross-linking arrangements will be made to give each participant the benefits of easy connectivity, which is the hallmark of the telescience testbed project.

5.5.4 Astronomy Testbed

We continued to make steady progress through the last quarter in implementing our Astronomy Testbed. The testbed uses an OASIS teleoperations package to provide the capability for operating a 16-inch telescope at the Sommers-Bausch Observatory, which is located at a remote corner of the University of Colorado campus. This setup is providing a convenient, flexible, and scientifically useful testbed for examining the many issues involved with remote interactive operations of a Space Science instrument.

The following tasks have been completed:

1. installation of a remote focus control to provide the remote observer with full control of the operation;

2. installation of a user catalog whereby any approved user can store a private list of selected targets for viewing. This is an automated system that saves the catalog from one session to another;

3. installation of search routine. This allows the observer to backtrack to an observed feature, and provides a freeze feature that prevents overshots;

4. The User's Guide is 10% completed;

5. installation of software to synchronize the remote and local controlling elements and ensure that the remote OASIS controller only sends commands when the local Apple Controller is ready; and

6. A basic testbed environment is complete. This environment includes the telescope; two remote sensing instruments/ the local controller; links for voice, data, and video; and, the remote OASIS teleoperations package.

Several Activities Are Planned For The Next Quarter

1. The distributed testbed, with its interface to the user-scientist, will be used by several science groups and critically evaluated.

2. The User's Guide and Help files will be completed.

3. A capability will be added to allow multiple users to control and/or monitor telescope operation simultaneously. Multiple users will be involved in this testbed to uncover issues involved with distributed control.

4. The remote OASIS will be moved into a university classroom to evaluate the excitement and educational benefits of telescience.

5. Many important lessons have been learned in this telescience testbed. These lessons are detailed in the enclosed interim report.

5.5.5 Colorado-Ames Testbed

The Colorado group has been supporting the life sciences testbed at Ames and is looking forward to an official start for this activity.

We are currently awaiting the final version of the Interface Definition Document (IDD) controlling the communication interface between OASIS and the other element of the testbed. Implementation in OASIS of the support to the communication requirements will start as soon as the IDD is formalized.

5.5.6 MSFC Testbed Support

A special V02.03.05 version of OASIS, working with four-color plane 5VAX II/GPX, has been specifically created and installed for demonstration at the Marshall Space Flight Center.

5.5.7 Astronomy Testbed

Lessons Learned and Recommendations Overview

The Astronomy Testbed at the University of Colorado (CU) uses the OASIS teleoperations package and commercial communication services to give us remote, interactive operation of a 16-inch telescope at the Sommers-Bausch Observatory (located on a remote corner of the campus). The testbed provides a convenient, flexible, and scientifically useful environment for examining the many issues related to remote, interactive operation of a space science payload.

The testbed was established to allow CU scientists to examine key telescience issues listed below. These technical issues have each been investigated in varying levels of detail with some expected and some perhaps unanticipated results. These results, including lessons learned and preliminary recommendations for space payload operations, are detailed in this report.

The testbed also provided some significant general insights into the advantages of the telescience style of operations. According to the users, telescience allowed them to reduce or eliminate some of the difficulties involved in using a general observatory (e.g., working outside in the cold and in the dark), while preserving the advantages of scientific experimentation at the observatory (direct control of operations, experimental and observing feedback, and the ability to react to unpredictable conditions). These general advantages will likely be the drivers in overcoming any technical challenges to the telescience mode of operations.

The astronomy testbed is made up of the following components:

1. ***Telescope:*** 16-inch F12 Cassegrain telescope by DFM
2. ***Photometer Instrument:*** UBV photo diode photometer by OPTEC-SSP3
3. ***CCD Camera Instrument:*** SONY
4. ***On-Site Controller:*** APPLE II-E
5. ***Commercial Phone Links:*** 1200 baud auto-answer Scholar modems over normal commercial phone lines
6. ***Video Network:*** 5 megahertz local area network
7. ***Slow Scan Video:*** Analog video signal at 35 second update
8. ***Remote Controller:*** OASIS (Operations and Science Instrument Support) teleoperations package executing on a MicroVAX-II workstation.

5.5.8 Technical Issues

ISSUE 1: What methods can be used to ensure the safety of on-site crew and the safety of the instrument and facility under remote control?

Approach/Lessons Learned:

1. Three levels of command pre-checks or interlocks are used: one at the telescope itself, one at the onsite controller, and one at the remote controller:
 - a. The telescope has absolute limits of operation, and will stop tracking if these limits are reached. At that time, control of the telescope is prohibited until a manual override is performed.
 - b. The on-site controller pre-checks the format of each command upon arrival from the remote controller, rejects commands failing the check, and returns the reason for the rejection.
 - c. The remote controller recognizes certain commands as hazardous and requires the operator's approval before transmission.
2. The onsite controller checks commands against time-varying limits. If a request is made for an out-of-limit command, the on-site controller will not execute the command and will return the reason for rejection.
3. The remote controller has conditional/time-varying pre-checks to verify an environment that is safe for the command, thus preventing the telescope from pointing at the sun.
4. Three kinds of limits have been implemented to help the user monitor telemetry:
 - a. **Absolute:** to check if an item is out of its allocated envelope;
 - b. **Delta:** to check if an item has changed by abnormally large amounts; and
 - c. **Trend:** to check if an item will exceed its allocated envelope if the current trend continues.

With these limits, the remote controller can reactively control operations.

Preliminary Recommendations

1. Use a combination of both on-site and remote control to assure safety.
2. Use conditional, dynamic pre-checks or interlocks to guard against potential safety violations.
3. Monitor conditions and trends for reactive control.
4. Provide the user with control over automatic pre-checks or reactions.

ISSUE 2: What are the effects of communication delays, and limited sensory information on the accomplishment of science objectives? How much feedback is needed to conduct experiments with confidence?

Approach/Lessons Learned

1. The use of figures to represent the telemetered orientation of the telescope seems to satisfy the needs of an observer to know the orientation of the telescope.
2. The use of absolute telescope slew moves (based on telemetry), rather than relative slew moves (based on time), has eliminated some of the problems of communication delays. The user should send one discrete instruction instead of a group of timed instructions to accomplish a task. An intelligent local controller would be used to ensure the absolute target was reached. With remote control, telemetry should be monitored to ensure target acquisition.
3. When, due to limited bandwidth, there is not enough sensory information to locate the exact position of the telescope, onsite acquisition software must be used to establish the position of the telescope. Establishing the exact location requires high data rates and low data delays, and (with limited bandwidths) can only be accomplished onsite.
4. When data delays were encountered and more than 30 seconds elapsed before acquiring telemetry feedback, the user often became anxious and sent the command repeatedly. To avoid this, the automatic procedure should contain a wait statement to prevent retries, while allowing the user to override the wait.
5. When the onsite controller fails to acknowledge commands sent by the remote controller, the remote controller will automatically retry the command three times. This allows any command to be retried without adverse impact.

Preliminary Recommendations

1. Commands should be structured so that they do not depend upon duration of transmission, and can be retried as often as necessary without confusion. This can be accomplished by the use of single commands that ask the on-site controller to move to a new location, or to change rates for a specified amount of time. Commands that ask the controller to start an activity that must be then stopped in a timely fashion, create problems for remote users. The problem can be solved if the command software is tied to the telemetry, so that relative commands can be restructured as absolute commands.
2. Displays should be structured so that data-driven figures can be defined by the user. It is our experience that figures rather than data numbers provide the best view of moving components.
3. There are certain activities which require full bandwidth. Without this kind of feedback, these activities must be accomplished on-site.

ISSUE 3: Can a single user operations interface provide a consistent and effective means for controlling a variety of science instruments and platforms?

Approach/Lessons Learned

1. The interface that is used for telescope control can apply to any RA/DEC pointing reference system. The need for common figures for such information as field-of-movement and graphs of counts versus frequency is widespread through many applications and disciplines.

2. A menu system which allows users to go through a hierarchy at will is useful both for the novice using a clear pathway, and the expert without a pre-defined pathway.

3. Color coding allows the user to recognize dangerous (red) conditions both in color and text notation (e.g., 'R' for a red high limit). One set of color standards should be used in all monitoring applications.

Preliminary Recommendations

One interface can work for a variety of instruments. This interface would have the following features:

1. the ability to drive figures, cartoons, graphic representations, and icons with telemetry data;
2. the ability to define figures interactively using a combination of standard and user-defined objects;
3. the ability to use menus for instruments and system control instructions;
4. the ability to set up self-explanatory menus to guide the user through particular activities;
5. the ability to use color to tag out-of-limit items; and
6. standard colors for standard conditions.

ISSUE 4: What is the effectiveness of user interface designs for telescience applications?

Approach/Lessons Learned

1. Astronomers have been active participants in this project and are eager to design the control interfaces, displays and safety controls.

2. The ability to accept an interface is directly related to the user's ability to mold that interface.

Preliminary Recommendations

Provide an interface to the telescience users which they can develop and tailor to their needs.

ISSUE 5: How do we coordinate instrument control with distributed users competing for a shared resource?

This issue will be addressed in the continuing testbed investigation.

ISSUE 6: What operation strategies are useful in situations where scientific observations are defined by targets-of-opportunity or specific environmental objectives, rather than being limited to block schedules?

Approach/Lessons Learned

1. This testbed provides for a user-defined list of observing objects, including the planets. This allows the user to define targets interactively, and to locate and track them automatically.
2. This issue will be addressed more fully in the continuing effort.

Preliminary Recommendations

1. Any operations system should allow users to store and retrieve information specific to their interests and objectives, based on current conditions.
2. Further recommendations will be made after further examination.

ISSUE 7: Allocation of control Q from total user involvement to total automation.

Approach/Lessons Learned

1. There must be one master controller. The local controller has the ability to take telescope control at any time and can give that control to the remote controller. The remote user can only give up control; he/she cannot send any commands to the telescope until the local controller allows it. When control is transferred, messages are transmitted to the new controller.
2. The local controller needs a mechanism to verify that the remote controller is still in contact Q as a precaution against communication losses.
3. This issue will be addressed in a continuing effort.

Preliminary Recommendations

1. Allow duplication of all appropriate functions on both the local and remote controllers, to allow easy passage of control between the two.
2. If the remote user is not able to contact the local controller, then safety should not be compromised.
3. Further recommendations will be made after further activities.

ISSUE 8: How can instruments and experimentation methods be designed to take advantage of the opportunities of telescience?

Approach/Lessons Learned

1. Design instruments to provide video as well as digital indications of pointing.
2. Problems have been encountered with this application during initialization. The telescope was not designed for remote initialization and currently requires some local initialization. All operations should be able to be remotely controlled.
3. The instrument hardware, the telescope, and the experiment should be designed to provide full feedback and visibility of hardware and observing conditions to the remote observer.

Preliminary Recommendations

1. Design instruments so that the video links can be switched between what the instrument is looking at and the instrument; both views are critical. A flexible field-of-view is also important.
2. For many search routines it is more efficient to include the algorithms within the onsite controller in order to avoid problems with data links and baud-rate limitations. The recommendations on experiment design will be made during the continued activity.
3. In continuing activities, we will implement experimental programs and sequences designed to take advantage of the opportunities of telescience.

5.5.9 Future Directions

It has been evident that a ground observatory provides an excellent testbed framework for examining the many key issues involved with telescience in the Space Station era. In continuing testbed activities we hope to:

1. Extend the automated capabilities of the local, onsite controller, in order to evaluate autonomous operations and to compare the relative benefits of autonomous versus teleoperations.
2. Extend the testbed framework interfaces to allow multiple users at separate physical locations to control the telescope and two instruments, both simultaneously and in a time-shared manner.
3. Apply the existing astronomy testbed framework and tools to a comparison solar application.

4. Extend the capabilities of the on-site controller to prototype the command interlocking and reactive control capabilities of the Operations Management System (OMS). This would allow us to investigate the primary telescience issue: *"Can we safely operate a complex mission while allowing direct, interactive control of the science payload?"*

5. Augment the testbed to allow examination of teleoperations within a dynamic envelope of resources, plus allocation of these resource envelopes.

6. Continue the testbed investigation to complete the examination of the eight original issues listed above.

5.6 CORNELL UNIVERSITY

The major finding from tests of currently established networks between Cornell and Arizona, and Cornell and Harvard is that these networks are very slow and in many cases unreliable. Tests have included file transfer and remote running of applications programs.

The best solution to this problem would appear to be the construction of specific applications programs on either side of the network with only minimal transfer of information over the network and good error checking (like OASIS?). This has not been done because it requires programming at the basic network level. Even if this is accomplished, the dropout problem must be solved if implementation of "near real time" applications are to be possible.

A summary of network access, activities, test results, and usage is given below:

1. Networks used:

- a. *Established:* ARPA/NSF, BITNET
- b. *Regional:* NYSERnet
- c. *Special purpose/dedicated links:* None

2. Functional use for each of the above:

- a. Email;
- b. Software porting (planned);
- c. Archive/database search (planned); and
- d. Data porting

3. Utilization of networks:

- a. Daily usage; and
- b. Typical volume: kilobytes (large image transfers not reliable or fast enough)

4. Performance:

- a. **Reliability:** - adequate for email
 - possibly inadequate for large image transfers
 - b. **Bandwidth:** - adequate for email
 - woefully inadequate for large image transfers
 - c. **Latency:** - acceptable for email
 - unacceptable for image transfer and remote software execution
5. Used for projects outside of TTPP. No other uses yet but likely use in SIRTf and reduction of IRAS data under astrophysical data program
6. Network enhancements needed to do a better job:
- a. higher bandwidth; and
 - b. enhanced reliability

5.7 UNIVERSITY OF MARYLAND

During this quarter, the primary activity has been to upgrade the hardware for the CCD camera system which will be used at Lowell Observatory. The CCD system which is used to carry out the telescience was shipped to Maryland at the end of the previous quarter and remained at Maryland for the entire quarter while we upgraded the hardware for totally remote operation (this upgrade is not funded by TTPP except for the communications aspects). It is expected that this upgrade will not be completed until the end of the summer. The upgrade includes automation of the filter wheel selection, the grating selection, and so on: items which have been varied manually until now.

We have investigated completion of a network connection to Lowell Observatory but because their equipment is in a state of flux, it is not yet possible to define the details needed for a SPAN node there. Access to Lowell for electronic mail through the SPAN node at USGS has been intermittent, as the USGS node and its connection to JPL have been down at different times. This has caused significant disruption of communications, although it has not had a direct impact on TTPP since those activities are limited by the upgrade in process on the camera.

5.8 UNIVERSITY OF MICHIGAN

The REMOTE COACHING system is steadily improving in its capabilities. Personnel in the Space Physics Laboratory are using the system on a regular basis, in order to validate the operation of the system. On a weekly basis, the expert systems programmer from the Robotics Laboratory is meeting with the users in the Space Physics Lab to get a report on its operation. Some rules have been found to be incorrect and more video pictures have been

needed to make it clearer for the users in the Space Physics Lab. The current version of the system is being used for maintenance of an interferometer. However, the final version of the system will provide three modes of operation, which are: inquiry mode, maintenance mode and diagnostics mode. The inquiry mode is used for by the uninitiated user to learn about the operation of the instrumentation used in the experiment. As the operator becomes more familiar with the equipment and terminology used, his use of the inquiry mode will diminish. In maintenance mode, the user is guided through a sequence of steps for performing some maintenance task. In our initial application it is the calibration of the interferometer. If the user follows each step exactly, the interferometer will be calibrated at the completion of all of the steps. The diagnostics mode is used to determine the cause of a failure in the system. In this mode, the user has determined that the system is not working correctly but may not know why it is not working correctly. After discovering the cause of the problem, the operator can then go into the maintenance mode and the operator is guided through a maintenance procedure as described above.

All three modes provide an option to stop the current operation and establish a communication link via modems with the real expert at the local control station (back at the university). After establishing the communication link, the COACHING system at the local site is brought up to a state of operation identical to that of the remote site. The concept of state for the expert system means the activation of the same rule, the same agenda, and the same facts. The difficult part in all of this was obtaining the same agenda for each system. The rules that are ready to fire are stored in the agenda and the order of their firing is dependent upon the order of the facts that were used in their activation. Thus, simply having the same rules on the agenda is not enough. The order of the rules on the agenda is also important. Our method of accomplishing this was to create another set of rules for storing, clearing the fact base, and then reloading the facts. As the facts are reloaded, a new agenda is obtained with the same rules as before, but with a reordering of the rules in the agenda. By going through this process both agendas at the remote site and at the local site to exactly the same state.

Since the modems have not yet arrived, we have not established communication between the remote systems at the Space Physics Laboratory and the local system at the Robotics Lab. However, we have temporarily set up a communications testbed within the Robotics Lab using a serial line communication between the Sun computer which will be used at the local station, and an IBM PC computer, which simulates the portable COMPAQ computer being used at the remote site. We are developing the communications software with this testbed while waiting for the modems to arrive. The additional work required to use the modems instead of serial lines will be minimal. With this testbed system, we have solved the problems of capture of a picture at the remote site, compression of the image, transmission to the local site, decompression and display on the SUN video monitor. We are now working on the software required for creating the dialog between the operator at the remote site and the expert at the local site.

5.9 MIT, ASTRONOMY

Networks Used: ARPA/NSF, Athena

Link to Remote Site: two dialup analog lines, generally used with one modem at 2400 and one regular handset; considering an interim upgrade to a Telebit modem that would give up to 17,000 bits/second.

Requirements

A minimum of T1 communications to the site in order to operate in real time for the telescience experiments was proposed and accepted. This would allow both images from an imaging research photometer and environmental images (weather, maintenance and troubleshooting). Use of this link would also extend the daylight hours to use a computer at the remote sight for image analysis, etc.

Functions

ARPA/NSF: used for email, small data file transfer, electronic bulletin boards, software transfer.

Athena: coexists with the campus ethernet and will be considered in this context as one entity. It is used to port software, work with (NFS) network file systems, and basically, has become integral to most computer activity. Data acquisition and instrument control currently does not take place in realtime over this route.

T1 communication to remote observatory: This will be used for instrument/telescope/observatory control and data acquisition, once it is in place, as well as, remote data analysis and recovery of temporarily stored data.

Time Utilization

ARPA/NSF: used at least hourly with probably no more than 5 Mbyte average daily volume.

Athena: used nearly constantly, average volume 10-100 megabyte per hour during the peak use periods.

T1 communication to remote observatory: planned for nightly use when it is clear for observing and computer usage during most other times. Likely volume is multi-megabytes per hour. Typically, it would be 30-130 Mbytes per observing run.

Performance

ARPA/NSF: marginal performance not good for realtime. Many sites not accessible, though in principle they should be.

Athena: generally good performance, though the bandwidth limits are being approached.

T-1 communication to remote observatory: not yet in service.

Use for Projects Outside of Telescience

ARPA/NSF: All other projects generally become involved in its use.

Athena: All other projects generally become involved in its use.

T-1 communication to remote observatory: will only be used for Telescience. It is hoped that this becomes the preferred mode of operating the observatory.

Network Enhancement

ARPA/NSF: Needs about a factor of 100 in speed in order to keep up with current usage.

Athena: An upgrade to FDDI (fiber) is planned. The dates of implementation have not yet been set.

T-1 communication to remote observatory: This is essential to the control and data acquisition part of our Telescience program.

Manned Remote Observing

This observing is taking place as planned and on schedule. It is to culminate in an observing run on the Kuiper Airborne Observatory. Preparation and implementation of this phase is a major part of our group effort for the next 2-3 weeks. Additional information is available in the last monthly report.

Optical disc archiving of data across an ethernet is progressing satisfactory.

5.10 MIT, Life Sciences

During this quarter, we have seen the "beginning of a coming together" of the various pieces of our telescience experiment and procedures. Arrangements were finalized with MIT Project Athena to utilize two of their Visual Workstations and two rooms to serve as the PI station and the telescience test conductor station. Lines and equipment are being set up. Coordination among Athena and Information Services personnel has been an occasional problem, which we are working to resolve.

Rick Fiser, Bob Renshaw and Chuck Oman have been working towards locating and procuring a C-band antenna. So far, the major hurdle has been finding a place at MIT which will permit permanent installation and still give the appropriate view of the heavens, free from microwave interference. To minimize costs, the antenna will be mounted at ground

level. KSC has arranged a lease with option to buy arrangement for the antenna to cover all possibilities.

Ilya Shubentsov continued working on the data display portion of the telescience workstation. At present, virtually all of the modules are partially written, but they are not complete. The main program, the interprocess communications code, the graphing code, and the menus are almost complete.

Braden McGrath continued working on the video control software. Using modified Athena software, a live video picture can be placed in one corner of the terminal screen. As an added feature, a single frame video picture can be placed in another location. A video menu to control the video has been developed. This currently consists of four scroll bar windows. The first three scroll bars are used to adjust the frame rate (F), resolution (R), and gray scale (G). The fourth scroll window represents the total bandwidth ($B = F \cdot R \cdot G$) available for a given experimental session.

A preliminary crew training session was held by Oman and Arrott at KSC in May to familiarize the surrogate Payload Specialists with the scientific and operational details of the experiment. This time was also used to refine the science experiment procedures prepared by Modestino and Arrott. The Experiment Payload Specialists picked up on the ideas presented quickly. Data lines (19.2 kbaud) are being installed by Contel and the nuances of the data format are almost completely defined.

Weekly teleconferences between MIT, KSC and PSI continued, as did work on the System Definition Document. The SDD documents our experiment goals and methodology.

Dr. Oman, together with Rick Fiser of KSC and Anthony Arrott of PSI, represented MIT at the Boulder meeting and participated in a joint presentation on the Life Sciences Testbed, which was very well received. Professor Laurence Young, Life Sciences Discipline Coordinator, was also present at the Boulder meeting. We made several useful contacts at the meeting, which we have since followed up on. A Telescience Life Science Discipline group was formed. Among other issues, the group discussed future plans for follow-on life sciences telescience activities. The group met again at NASA Ames in early April to draft an advisory document.

5.10.1 KSC Activities

The Human Use Protocol proposal has been forwarded by BIO-1 to the Human Use Committee for review and approval.

An AVO was drafted to initiate selection of the six Experiment Payload Specialist candidates. After they are selected, the EPS candidates are medically certified and are currently being trained in telescience operations.

Manrating of the U.S. Lab Sled was completed on April 26, 1988.

Contel ASC is progressing on the installation of the 19.2 Kb data link. The cable was installed in the BDCF on April 28, 1988, and a loop test of this circuit was completed on May 4. Telephone modifications to support voice communication were completed on May 4, 1988.

The data acquisition and transmission format development with MIT is continuing. Data system software development began the second week in May.

Preliminary KSC inputs to the System Design Document (SDD) have been completed. These inputs will be combined with inputs from MIT and PSI.

KSC inputs to the Life Sciences Telescience Advocacy report have been completed and transmitted to Larry Young (MIT/Stanford). These inputs will be combined with similar inputs from ARC and JSC to draft a Life Sciences Telescience Advocacy Document, which will eventually be submitted to key NASA HQ personnel.

5.10.2 MIT-PSI Life Sciences

Besides the ongoing weekly management of the project (Nijhawan), Payload Systems (Arrott) also made a presentation at the TTPP meeting in Boulder on the scientific goals of the TLSTB and the current status of its development. PSI also attended the meeting with Athena Computer Services Personnel to finalize the remaining details for the use of their facilities for the testbed.

The System Definition Document is nearing its first complete draft. We are aiming for completion of this draft prior to the test bed scientific operations in early June.

5.11 PURDUE UNIVERSITY

5.11.1 Equipment and Software

The SUN 3/60C was installed during late February and early March. The SUN is connected to the Internet with a domain name of *newton.ecn.purdue.edu*. The 141 megabyte disk drive for the SUN broke down within the first two days. A replacement was obtained early in March and has worked well since.

Oracle was installed on the SUN during March.

Also, the LoDown 800 megabyte WORM optical disk arrived during March from Arc Laser Optical Technology (ALOT). Tests of the optical disk have indicated one concern. The software that came with the system will only allow one to copy an entire volume (floppy disk or disk drive), not just a file or folder, to the optical disk. Therefore, if the file being copied does not fill the entire disk that it is on, a lot of space is wasted on the optical disk. ALOT is upgrading the software to allow one to copy a file or a folder at a time. They hope to have the new version of the software done in early June.

5.11.2 Spectrometer/Multiband Radiometer Database

A prototype of the spectral database catalog has been developed using Apple's Hypercard. Information about the experiments from nine of the thirteen files, including the location, researcher, instruments, and scene and/or species have been included in the catalog "stacks". The prototype was demonstrated at the Telescience meetings in Boulder, Colorado, during early March. The Field Research spectral data base catalog "stacks" are available to anyone who would like a copy.

The eleven files that define the catalog for the spectral data base have been loaded into Oracle on the SUN 3/60. The interface for the user is now being implemented.

5.11.3 University of California Santa Barbara's BROWSE System

During April, we successfully accessed BROWSE via a 9600 baud dialup using the US Robotics modems. The sessions went very well. This has been the most pleasing connection to BROWSE from a user point-of-view. The session went much better than any connection we have had via the Internet and, of course, better than the slower dialup speeds.

5.11.4 University of Wisconsin's McIDAS System

During May, we received the latest copy of the McIDAS PC software which requires only a color video monitor for accessing and displaying GOES imagery. The system works well on our IBM PC/AT system.

5.11.5 University of Colorado's OASIS

We have been working with Elaine Hansen and Alain Jouchoux to obtain a copy of OASIS for testing remote control of the Solar Mesosphere Explorer satellite. The system that we are going to install OASIS on is a VAXstation 2000 which arrived in April. However, some of the software is missing for it. As of the end of May, the software still has not arrived from DEC. After the software arrives and is tested, we will obtain a copy of OASIS from the University of Colorado to install on the VAXstation. From our discussions with Colorado, we have determined that OASIS should be relatively easy to port to the VAXstation 2000.

5.11.6 Earth Sciences Group

Representatives from the Earth Sciences group met after the Telescience meetings closed in Boulder. Representatives were there from University of Colorado, UCSB, Purdue, University of Wisconsin and University of Rhode Island. Items discussed included the pilot experiment and presentations to the discipline directors at NASA Headquarters. The universities were encouraged to discuss individual and collective projects with their respective disciplines at NASA Headquarters.

A field campaign experiment is being considered for either Indiana or California, as a part of a larger ongoing experiment. The universities are currently determining their roles in the campaign experiment.

5.12 UNIVERSITY OF RHODE ISLAND

As we have mentioned in previous communications, our general goals in the TTPP project are to investigate and develop ways of providing efficient remote access to digital image archives, i.e., to develop image browse software for accessing image archives. As of the end of this reporting period, we have two essentially complete implementations of the software: one for use at DSP sites on the SPAN network, and one for use on an IBM PS/II using a dialup connection to our archive. In this report, we will describe an important detail of our approach, mention major events during the quarter, and indicate our plans for the next several months.

Again as we have mentioned, part of our general approach to the remote access problem is to construct an image pyramid for a given image, each level of which is a reduced resolution representation of the original and to send successive levels of the pyramid, starting with the lowest resolution level, until the user stops the process either to abort or to ask for an just an inset area at higher resolution. A fundamental parameter in this is the function by which the pyramid is generated from the original image. Various functions are possible and have been used for a variety of applications, e.g., means, median values, etc. We think it is worth noting that for our AVHRR application, in which the basic objective is to allow a viewer to decide whether an image contains useful data and to determine its type in << one minute (and likely for a variety of other remotely sensed image data, as well), a simple sampling function is adequate. A sampling procedure, rather than some more complex function, means that there is minimal computational overhead, that the entire image does not need to be in memory before transmission can begin, and that there is no redundancy (or computational overhead in avoiding it) in sending an image. Sending a complete $n \times n$ byte image requires only $n \times n$ bytes. We were surprised that such a simple scheme works so well. Maybe there is a lesson in this. As far as significant events or activities during the quarter, we would like to mention four. First was our demonstration of our basic PS/II implementation in Boulder in March. This showed that even at 1200 bps, it was possible to browse a remote archive and meet or nearly meet the objective mentioned above. Second, though we did not attend the Image Compression Conference in Utah, we have consulted with a local expert, Peter Swazek in our EE Dept., who has helped us identify a combination of several computationally cheap techniques which can be easily added to our approach. We may be able to achieve >40% loss less compression with them. Third, during the Second New England/Canadian Ocean Technology Exchange Conference held here at URI recently, we demonstrated our system to representatives of the Bedford Institute of Oceanography of Nova Scotia. They are putting together an AVHRR archive and have expressed strong interest in adapting/adopting our system. Lastly, one of our students has begun to implement "intelligent interface" functionality into our browser. The basic idea is to use a machine learning classifier algorithm to learn the characteristics of the desired images from

the first "few" browsed.

Our plans for the next several months have three foci. We intend to release our software more widely, to more DSP-SPAN sites, in order to gain additional user experience. We will implement and experiment with various compression schemes. Finally, we will push hard on the intelligent interface implementation. Our goal here is a prototype by September 1988.

5.13 RENNSELAER POLYTECHNIC INSTITUTE

The activities of the RPI/LeRC team during this period involved both software and hardware development. In the area of hardware development at RPI, we have identified the science experiment to be used in the first trial of the telescience testbed. It consists of a nucleation study of fluoride glass at temperatures just below the melting point. This will be done by observing a small glass sample under indirect lighting which enhances the viewing of the nucleation sites within the sample by quadrature light scattering. The creation and growth of the crystals as a function of temperature will be observed and recorded. A small oven has been modified to accept the light source and the controller has been interfaced to an AT. This experiment will be done in three phases:

1. manually operated;
2. remotely operated at RPI; and
3. remotely operated at LeRC

The type of video to be used, i.e., analog or digital, will also be varied. Software development was the main effort during this period, as we finally received the complete Sun system. The desired format follows.

5.13.1 On the Sun--(Control Site)

A three process, three window, program will be running on the Sun. Process #1 will periodically request a new video picture from the remote site and display it in window #1. Process #2 will periodically request an update of analog information from the site and display the latest update along with the previous nine updates in window #2. Process #3 will accept keyboard requests for command transmission, format the command and transmit it. The latest command will be displayed, as well as the previous nine in window #3.

5.13.2 Transmission

The Sun will communicate with the remote site via a 9.6kb dialup modem. The above three processes will time share this facility.

5.13.3 On the AT Clone--(remote site)

At the remote site the 9.6kb modem will communicate via RS-232 with an AT clone. The clone will control the experimental equipment and also contain a frame grabber for video digitalization. On appropriate command from the control site, the clone will execute the desired action and transfer the requested data to the control site.

Efforts at both RPI and LeRC during this period have been focused on creating the various subroutines for the Sun (UNIX/OS), the AT clone (MS-DOS/OS) and the communication link. Although OASIS was considered, it could not be used at this time since it was not ported to a UNIX system and did not handle video files. The following major requirements were accomplished and tested during this period:

1. display of digital video pictures from the AT frame grabber on the Sun-RPI
2. operation of the frame grabber on the AT-LeRC
3. control of an oven controller by the AT-RPI
4. control of an oven controller by the Sun through the AT-RPI
5. control of stepper motors by the AT-LeRC

Creation of other required processes and the integration into one program (3?) on the Sun and one on the AT remains a difficult but high priority effort.

5.13.4 Plans for the Next Quarter

During the fifth and final quarter, we hope to complete the following:

1. installation of a teleconferencing net between LeRC and RPI.(Lack of equipment prevented completion as planned this quarter);
2. full scale inhouse glass experiments at RPI;
3. initial remote experiments at LeRC.

5.14 SMITHSONIAN ASTROPHYSICAL OBSERVATORY

5.14.1 Programmatic Statuses

During the fourth quarter, March through May 1988, a number of major programmatic activities were carried out. At the TTPP II meeting in Boulder, March 7-9, a presentation of the activities at SAO was made. A splinter meeting of the astronomy PIs was also held. The following topics were discussed at the splinter meeting: use of OASIS, data compression, network transmission and interoperability of catalogs.

The TTPP astronomy PIs were polled with regard to preliminary results from their TTPP activities. This data was to provide background information for use at NASA Headquarters in compiling some early information on the results of the TTPP activities. Secondly, the TTPP astronomy PIs were polled on their experiences so far in use of the networks. This information was digested and is provided as the astronomy discipline input for this quarterly

report.

A no-cost extension to the SAO subcontract for TTPP was granted through 31 October. Since no further funds were provided, the present activities will be spread out over the extension time period.

5.14.2 Technical Statuses

The major technical advancement in the last quarter is the completion of the microwave link between Tucson and the Ridge on top of Mt. Hopkins. This forms a LAN for the SAO MicroVAXes in Arizona with two in Tucson, one at Steward Observatory and one on Mt. Hopkins. One of the machines in Tucson, agilely, is a class B node and serves as a gateway to the University of Arizona campus. The LAN also has the VAX gamma in Tucson and the VAX, Anile, on Mt. Hopkins connected by the microwave (T1) link. We can now login on agilely via the Internet from Cambridge and then login on anile. Unfortunately, the University of Arizona has not yet been able to broadcast the routing for Annie, so that we can log in directly. This is being looked into.

The main purpose for the microwave link was to provide for a network connection to the MicroVAX anile which will be used for data acquisition from the new IR camera. This camera is nearing the end of development and it is hoped that it can be used at the telescope for the first time at the end of June. In preparation for this, SAO has been developing data acquisition software for arrays to be run on MicroVAX GPX under Ultrix. This software is nearing completion and is ready for runtime testing. A demo of the software was run in Tucson for the University of Arizona's Steward Observatory. The binary of the software was downloaded over the Internet to Tucson (about 0.5 MB binary file). We have also installed IRAF on anile. This was accomplished remotely from Tucson over the microwave link.

Recently, our experience with the Internet connection to Tucson has been poor. For the last half of May, we were unable to connect to Tucson. This is being looked into further. We are eagerly waiting for the NSN connection to be made at Tucson.

5.14.3 Activities Planned for the Next Quarter:

We are anticipating running the IR camera at the telescope in June. To accomplish this will require substantial support from Cambridge by our software personnel. We anticipate a period of activity during the next month, when the data acquisition will be remotely installed, debugged, and upgraded, as the IR array is brought into an operational mode. The network connections will be the key to this activity.

5.15 STANFORD UNIVERSITY

The Stanford effort of the Telescience Testbed Pilot Program is directed towards the

development of multimedia telescience workstations for a variety of real-time instrument control and monitoring functions. The two types of computer workstations being used are DEC VAXstation II workstations running under the VMS operating system and Sun 3 workstations running under the UNIX operating system. In order to support real-time data display and instrument commanding, the University of Colorado OASIS software package has been installed on the VAXstation and the NASA Transportable Applications Executive (TAE) is being planned for installation on the Sun workstation. The VAXstation/OASIS interface is planned to be implemented for a simulation of the Spacelab-2 mission, to determine the requirements for realtime data transmission in space operations. One goal of the Spacelab-2 simulation is to capture the transmitted data and distribute the data to computer workstations on a local area network. The Sun/TAE interface is planned to connect to the Space Station Testbed Facilities at Johnson Space Center to evaluate the interfaces and resources being planned for science experimenters. The initial project involves duplicating the data display and command system which ties into the payload simulator in the Space Station Testbed. Another joint effort with the group at the University of California at Berkeley has been to explore remote operations of EUVE prototype hardware from the Stanford STAR Laboratory. The Telescience Testbed activities also compliment joint activities between Stanford University and Goddard Space Flight Center, Johnson Space Center, and Kennedy Space Center.

The shared computer facilities at the Stanford STAR laboratory have been undergoing a major change in the last several months. The cluster of VAX 11/780s and 11/750s have been replaced by MicroVAX based file servers and dependent MicroVAX compute servers and VAXstation workstations. Two independent file servers have been set up; one under the VMS operating system and supporting dependent workstations under a Local Area VAX cluster, and the other under the Ultrix (VAX UNIX) operating system and supporting dependent workstations by the Network File System (NFS). The STAR laboratory computer system is designed to provide basic computing support to the laboratory, and to more fully support a workstation environment by providing operating system maintenance and access to peripherals, such as printers for workstations throughout the laboratory. Both the VMS and Ultrix MicroVAX systems are connected to the ARPAnet (including the Nasa Science Internet and NSFnet) and the NASA Space Physics Analysis Network (SPAN).

Negotiations with Sun Microsystems have resulted in orders being placed for a Sun 3/260 workstation for the Stanford STAR Laboratory aspects of the Telescience Testbed Pilot Program and a Sun 3/60 workstation to be placed at NASA Headquarters. The STAR Laboratory Sun 3/260 workstation has been received and setup, and Version 3.5 of the Sun Unix operating system has been installed. Portions of the TeleWEn (Telescience Workstation Environment) have been installed from the database at RIACS, and additional subsets of the TeleWEn library will be obtained as the library contents are reviewed. The delivery of the Sun 3/60 workstation for NASA Headquarters has been delayed as a result of the current memory chip shortage.

The Transportable Applications Executive (TAE) software package is being explored as a means of using computer workstations for spacecraft instrument monitoring and control. A demonstration instrument interface based on TAE has been received from Goddard Space

Flight Center and was brought up on the Sun 3/260 workstation. This demonstration program is based on the High Resolution Solar Observatory proposed for future Spacelab flights, and provides a simulation of controlling the operation of optical instruments viewing solar features. The demonstration program has been successfully installed and tested. It is planned to interface the program to a payload simulator running on another computer in order to provide a more realistic simulation of instrument commanding. In the near future, it is intended to interface the TAE workstation with a computer running an identical payload simulator at Johnson Space Center. In addition, the complete TAE+ package has been requested and will be installed on a Sun 3/260 workstation. The intent is to begin to develop command and data display interfaces for instruments that have flown on Spacelab-2 and are being developed for the Shuttle Electrodynamic Tether.

A similar effort is involved in the evaluation of the University of Colorado OASIS package to determine how it can be interfaced to display science and engineering parameters in a particular application. Another goal is to develop appropriate connections to a payload simulator for commanding purposes. The Oasis software has been installed at Stanford University on a GPX VAXstation running the VMS operating system. The examples and interface definitions are being studied in order to understand how to customize the input and displays for specific uses such as the simulation of the Spacelab-2 mission.

One aspect of the efforts for a simulation of the Spacelab-2 mission is the development of a workstation based display of the Shuttle Orbiter to indicate both predicted and realtime parameters important to the experiments being conducted. The display shows the electron trajectory emitted by a low power electron source and vectors indicating the direction to the sun and the center of the earth, the earth's magnetic field direction, and the direction of motion of the Orbiter. The code which provides this display on a Silicon Graphics IRIS workstation has been modified to access display parameters from another computer across an ethernet interface. The modified code has been tested by accessing display parameters from remote workstations running under both the UNIX and VMS operating systems, through a standard ethernet interface. Several interesting problems developed in the course of the communications program development. The first is that the floating point representations under the VAX architecture are different than those used on the Silicon Graphics and Sun workstations, which use the IEEE floating point standard. The difference could be easily solved by converting the numbers at the source workstation, but it complicates the development of a portable code for standard communications. The second problem concerns the way spawned processes interact under the UNIX operating system versus the VMS operating system. A spawned process under UNIX can communicate with the parent process via a mode called a non-blocking read in which a spawned process waiting for external input will not force the parent process to also wait for the input. The non-blocking read is not currently possible under VMS, so that other solutions to the communications handshaking needed to be developed. Evaluation of the code is underway to determine if there is a program structure that can minimize the differences in the code in order to make the code more portable.

A cooperative rapid-prototyping project has been underway with Kennedy Space Center to develop a computer interface for shuttle tile inspection. The first part of the project has

developed a voice entry and verification system to input tile step and gap measurements directly into a relational database. The voice system consists of a voice recognition unit and a speech synthesis unit which are connected to an ethernet based terminal server by standard terminal lines. The voice recognition unit converts human voice into digital characters and relays the information to a computer workstation which enters the values into a database. Input verification is achieved by echoing the input data back to the user through the speech synthesis unit. A system is being implemented at Stanford STAR Laboratory which will be identical to the system being used at Kennedy Space Center for tile automation project. A voice recognition unit and a speech synthesis unit have been received by and an ethernet based terminal server is on order. The intent is to use the voice system as a portion of a multimedia telescience workstation.

Discussions have been held with personnel from Stanford University, SRI International and RIACS about developing the Sondrestrom Incoherent Radar Facility in Greenland as a remote Telescience Testbed project. The Sondrestrom facility is currently funded by the National Science Foundation to study atmospheric and ionospheric phenomenon at high geomagnetic latitudes. The current mode of operation requires visits by outside science users to perform their research, particularly for study of phenomenon requiring real-time interaction. The remote location of the facility, realtime data requirements, and moderate initial data rates suggest the Sondrestrom facility as an appropriate model for a remote Telescience research site. The facility computer and communications networks are being evaluated, and possible upgrade options are being developed to be explored for continuation of the Stanford Telescience projects.

5.16 UNIVERSITY OF WISCONSIN

Telescience efforts at the University of Wisconsin have resulted in advances in two main areas during the past three months:

1. improvements of IBM PC software designed for the reception and display of McIDAS data products; and
2. establishment of a connection to the USAN (NSFnet) ethernet in our building.

5.16.1 IBM PC Software and the McIDAS Database

We have modified our version of IBM PC software so that only a color video monitor is necessary for accessing and displaying GOES visible, IR, and water vapor imagery. The older version only worked with both monochrome and color displays operating simultaneously. The software runs on an IBM PS/2 or an AT equipped with an EGA and enhanced color display. The package uses a Telebit modem and standard asynchronous dialup to access the McIDAS database. It is also compatible with a Hayes 1200 or 2400 Baud modem but the data transfer rate is greatly reduced from the 18K baud that is possible with the Telebit modem. The software also includes a scheduling option to allow automatic access of a time sequence of images useful for cloud animation.

The software is available upon request to TTPP participants. Lindsay Feuling, who can be reached at (608) 263-4494, is largely responsible for this update and will be responsible for distributing the software and helping you get started.

Copies of the software have been distributed to Purdue, UCSB, and to the University of Colorado-LASP. We are awaiting feedback from these users.

Please bear in mind that this software displays only a small subset of the real time data products that are accessible in the McIDAS database. A recent addition is AVHRR data via our DOMSAT link. If you have questions about the list of products available, feel free to contact us.

Connection to the USAN (NSFnet) TCP/IP Network

We have recently made a connection in our building to the USAN ethernet (NSFnet), using an IBM AT which will be the foundation of a McIDAS bridge. Our new host name is "*McIDAS.ssec.wisc.edu*" and is at IP address 128.116.12.97. An anticipated change in our campus configuration may require a change of address. Our host name is known to our campus gateway (STEER at 128.116.12.1). We have tested this connection using a commercial software package purchased from FTP Software, Inc. Results of the testing have verified the integrity of the hardware. We have been able to establish contact with a number of foreign hosts for the purpose of FTP operations. Testing of email operations using the USAN connection have revealed that a number of reliability problems still exist. We suspect that the problem lies in the mail relay host we are utilizing. We are continuing to work the problem. My alternate email addresses are:

RGDEDECKER@MCIDAS.SSEC.WISC.EDU ;
RGDEDECKER@VMS.MACC.WISC.EDU (ARPANET); and
RGDEDECKER@WISCMACC (BITNET)

The software package purchased from FTP Software, Inc. includes a development package which supports the TCP/IP and FTP. We are beginning efforts to develop software to establish a bridge between McIDAS and the NSFnet. We discovered a problem that required us to utilize an upgraded development package. We recently received the software update from FTP Software, Inc. and have resumed testing. Until we complete the bridge software, a path for providing McIDAS data products exists but requires manual operator intervention.

Appendix 1 TTPP List of Acronyms

TTPP List of Acronyms

AAS	(American Astronomical Society)
AGC	(Automatic Gain Control)
AIPS	(Astronomical Image Processing System)
ALOT	(Arc Laser Optical Technology)
Andrew	(Multimedia mail system with capabilities similar to Diamond; basis of Carnegie-Mellon EXPRES system)
ARC	(Ames Research Center)
ARPA	(Defense Department Advanced Research Projects Agency)
ARPANET	(Wide area data network supported by ARPA)
AT	(Astrometric Telescope)
ATF	(Astrometric Telescope Facility)
AVHRR	(Advanced Very High Resolution Radiometer; on the nimbus series of satellites. Run through NOAA)
B&W	(Black and White Display)
BARRNET	(Bay Area Regional Research Network)
BAUD	(not an acronym; a unit of signaling speed; refers to the number of times the state or condition of the line changes per second)
BCE	(Bench Checkout Equipment)
bps	(bits per second)
CAS	(Canadian Astronomical Society)
CCD	(Charge Couple Device; a technology for converting images into electrical signals)
CCSDS	(Consultative Committee for Space Data Systems)
CDP	(Command, Data, and Power interface unit; part of the EUVE instrument)
CLIPS	(A programming language for expert systems. A copy of the source program (written in C) was sent to U of Michigan from Johnson Space Center, Mission Support Directorate, Mission Planning and Analysis Division. It is in the public domain and has been installed on several systems, (IBM PC -Microsoft C, Sun, Dec.)The only restrictions to its use is that you can not sell it.)
CODEC	(Co-der/Dec-oder)
CSDF	(Commercial Space Development Facility)
CUI	(Common User Interface)
DEC	(Digital Equipment Company)
DMIL	(Direct Manipulation Interface Language)
DSP	(Digital Signal Processing)
EPS	(Experiment Payload Specialist)
EUV	(Extreme Ultraviolet)
EUVE	(Extreme UltraViolet Explorer)
EXPRES	(Experimental Research in Electronic Submission)
FUV	(Far Ultraviolet)
FRICC	(Federal Research Internet Coordination Committee)
GETSCI	*

GOES	(Geostationary Operational Environmental Satellite)
GPX	(Graphics Processor Workstation for MicroVAX II)
GSFC	(Goddard Space Flight Center)
HCIG	(Human-Computer Interface Guide)
HIPS	(Human Information Processing Laboratory's Image Processing)
HRPT	(High Resolution Picture Transmission)
HUP	(Human Use Protocols)
IAPPP	*
IBM	(International Business Machines)
IDL	(Interactive Data Language)
IGBF	*
IGBP	(International Geosphere Biosphere Program)
IL	(Intermediate Language)
IMS	(Instrument Management Services)
Ingres	(Database)
IOMS	(Instrument OMS)
IPAC	(Infrared Processing and Analysis Center at Caltech)
IRAF	(Image Reduction and Analysis Facility)
IRAS	(Infrared Astronomy Satellite)
JPL	(Jet Propulsion Laboratory)
JSC	(Johnson Space Center)
JVNCC	(John Van Neuman Computing Center)
KSC	(Kennedy Space Center)
KSCBCF	*
Kermit	(File Transfer Program)
Kiwi	(not an acronym; a "flightless bird" consisting of prototype EUVE electronics)
LAN	(Local Area Network)
LASP	(Laboratory for Atmospheric and Space Physics)
LCC	(Local Controlling Computer)
LIB\$TPARSE	(VAX/VMS library routine that provides a table driven parser. Used for the initial version of the CSTOL parser for OASIS)
LSTB	(Life Sciences Testbed)
Magic/L	(interactive programming language developed by Loki Engineering, Inc.)
McIDAS	(Man Computer Interactive Data Access System)
MIT	(Massachusetts Institute of Technology)
MMSL	(Microgravity Materials Science Laboratory)
MMT	(Multiple Mirror Telescope on Mt. Hopkins, AZ)
MSFC	(Marshall Space Flight Center)
NASA	(National Aeronautics & Space Administration)
NASA SELECT	(NASA run TV channel which carries NASA related events)
NASCOM	(NASA Communications- mission critical)
NICOLAS	(the inter-network gateway at Goddard Space Flight Center)
NOAA	(National Oceanic and Atmospheric Administration)
NOAA-G	(Name of the NOAA polar orbiting satellites)

NRAO	(National Radio Astronomy Observatory)
NSE	(Network Software Environment)
NSF	(National Science Foundation)
NSFnet	(Data network supported by NSF)
NSI	(NASA Science Internet)
NSN	(NASA Science Network; TCP/IP part of NSI)
NTSC	(Standard video signal format)
OASIS	(Operations and Science Instrument Support)
OMS	(Space Station Operation Management System)
OMS/PMS	(Operations Management/Platform Management)
OMSS	(Operation Management Services)
OSSA	(Office of Space Applications & Applications)
PI	(Principal Investigator)
PSI	(Payload Systems, Inc.)
Project	(MIT student network)
RA	(Research Assistant)
RCC	(Remote Commanding Computer)
RFH	(Remote Fluid Handling)
RGB	(Red, Green, Blue Video Display)
RIACS	(Research Institute for Advanced Computer Science)
ROM	(Read Only Memory)
RS-232	(Standard for serial data transmission)
SAIS	(Science and Applications Information Systems)
SAO	(Smithsonian Astrophysical Observatory)
SCS	(Software Control System)
SIMBAD	(Primarily a bibliographical cross reference database of 700,000 stellar and 100,000 non-stellar objects, which can be logged into remotely from around the world; set of identifications, measurements and bibliography for astronomical data)
SME	(Solar Mesosphere Explorer satellite)
SOP	(Science Operations Subgroup)
SPAN	(Space Physics Analysis Network)
SPIE	(Society of Photo-Instrumentation Engineers)
SS	(Space Station)
SSE	(Software Support Environment)
SSIS	(Space Station Information Systems)
SSL	(Space Sciences Laboratory at UC, Berkeley)
SSP	(Space Station Program)
STScI	(Space Telescope Science Institute)
TAE	(Transportable Applications Executive)
TATS	(Thaw Atmospheric Telescope Simulation)
TCP/IP	(Transmission Control Protocol/Internet Protocol)
TDRSS	(Tracking and Data Relay Satellite System)
TeleWEn	(Telescience Workstation Environment)
Terracom	(a company name)

TFSUSS	(Task Force on Scientific Uses of Space Station)
TIF	(Telescope Interface Unit)
TIGS	(Testbed at LASP)
TMIS	(Technical Management Information System)
TTPP	(If you don't know this by now it's too late!)
UC	(University of California)
UCB	(University of California, Berkeley)
UCSB	(University of California, Santa Barbara)
UIL	(User Interface Language)
Unify	(Database)
UofA	(University of Arizona)
USE	(User Support Environment)
USRA	(Universities Space Research Association)
UW	(University of Wisconsin)
VISTA	(another image processing system)
WAN	(Wide Area Network)

Appendix 2 TTPP BIBLIOGRAPHY

BIBLIOGRAPHY

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This article describes the concept of a workstation and the European Space Operations Centre in Darmstadt.

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This article briefly covers the first year of the Experimental Research in Electronic Submission (EXPRES) project and information on UM EXPRES.

Bennett, Elliot, *HOLOP: A Case Study of Advanced User-interface Design for Interactive Control of Space Experiments*, DFVLR IB 333 - 88/5, 24 pp., DFVLR, Institute for Space Simulation, Cologne, West Germany, June 1988.

This paper details advanced concepts in user-interface design implemented in the computer program HOLOP Ops. HOLOP Ops was designed to provide a simple, easy, and fast user-interface for remote, interactive control the HOLOP facility aboard the D2 Spacelab mission. Such a user-interface is achieved by implementing full graphics capabilities (including pictures, icons, graphs, and mouse/cursor control) as well as full text displays and control in a transparent, integrated environment for experiment observation and control. The advantages and capabilities of this program's user-interface are described and analyzed for their ability to enhance space based science productivity in the Space Station era.

Bienz, Richard A. and Larry C. Schooley, "A Survey of Computer Networks," Technical Report TSL-001/87, 85 pp., Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ, February 1987.

A summary of existing wide-area computer networks and their attributes and evaluation of their possible use in the University of Arizona TTPP testbeds.

Cellier, Francois, *Teleoperation of the Thaw Telescope at the Allegheny Observatory: A Case Study*, Technical Report TSL-004/87, 56 pp., Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ, December 1987.

Primary purpose of this document is to define the intermediary language to be used for computer-to-computer communication between the local controlling computer at Allegheny Observatory and the remote commanding computer which will be located at the University of Arizona. Overview of plans leading to teleoperation the Thaw Telescope at Allegheny Observatory is also discussed as well as control loops, sensors, safeguard error messages.

Chakrabarti, Supriya, Carl A. Dobson, and J. G. Jernigan, "Telescience at the U. C. Berkeley Space Science Laboratory," *Bulletin of the American Astronomical Society*, vol. 19, p. 744, Space Sciences Laboratory, U.C. Berkeley, June 1987.

The University of California, Berkeley is a member of a University consortium developing methodologies for remote design, development and operation of space instrumentations, collectively termed *telescience*. We will discuss our efforts in extending an existing local software control system to allow the development and sharing of software between remote sites. We are developing a methodology for the remote operation of instrumentations utilizing networks such as the ARPANET. These techniques have already been demonstrated over a local Ethernet. These two areas of investigations address the teledesign and teleoperation components of telescience.

Chakrabarti, Supriya, Carl A. Dobson, George C. Kaplan, Herman L. Marshall, Michael Lampton, Roger F. Malina, Stuart Bowyer, and Jeff Star, "Astronomical Data Analysis from Remote Sites," *Astronomy from Large Databases, Scientific Objectives and Methodological Approaches, EOS Conference and Workshop Proceedings*, vol. 28, p. 295, Space Sciences Laboratory, UC Berkeley & Remote Sensing Research Unit, UC Santa Barbara (J. Star), Berkeley, CA, January 1988. Also available in Space Astrophysics Group Contribution Number 329.

Given the progress in the communication technology, it is expected that during the space station era the mode of instrument operation and data analysis will be dramatically different. A consortium of several universities and NASA centers are evaluating various aspects of design and operation of scientific instruments and data analysis over various computer networks from a remote site. Such a scheme has officially been termed *telescience*. We will report on the development of methodologies for *teledesign*, *teleoperation* and *teleanalysis* and the verification of these concepts using the Extreme Ultraviolet Explorer (EUVE), a satellite payload scheduled for launch in 1991. The EUVE telescopes will be operated remotely from the EUVE Science Operation Center (SOC) located at the University of California, Berkeley. Guest observers will remotely access the EUVE spectrometer data base located at the SOC. Distributed data processing is an integral part *telescience*. We will describe our experience with the Browse system, currently being developed at the University of California at Santa Barbara through a grant from NASA for remote sensing applications. We will discuss the suitability for its adoption for astronomy applications. Browse allows the examination of a subset of the data to determine if the data set merits further investigation. The examination can be as simple as looking for a specific data element based on its location, date of observation, quality indicator, spectral coverage etc. It also allows the viewing of data in various modes depending upon the available resources at the user's end (e.g., graphics terminal vs. dumb terminal), level of data compression applied, required display format etc. and its transmission over a network to a local graphics display station.

Gallagher, Maria L., *Telescience Testbed Kickoff Meeting Minutes*, RIACS TR 87.25, 26 pp., RIACS/USRA, Moffett Field, CA, September 1987.

The kickoff meeting for the Telescience Testbed Pilot Program was held on July 30-31, 1987 at NASA Ames Research Center. These are the minutes of that meeting.

Gallagher, Maria L., *Telescience Testbed Pilot Program Meeting II Minutes*, RIACS M88.1, RIACS/USRA, Moffett Field, CA, March 1988.

The TTPP II meeting was held on March 7-9, 1988 in Boulder, Colorado. These are the minutes of that meeting.

Gallagher, Maria L. and Barry M. Leiner, *Telescience Testbed Pilot Program First Quarterly Report*, RIACS TR 87.26, 35 pp., RIACS/USRA, Moffett Field, CA, September 1987.

The Telescience Testbed Pilot Program participants are required to issue reports to NASA Headquarters on a quarterly basis. This is the first quarterly report, covering the period April 28, 1987 through August 31, 1987.

Gallagher, Maria L. and Barry M. Leiner, *Telescience Testbed Pilot Program Second Quarterly Report*, RIACS TR 87.31, 57 pp., RIACS/USRA, Moffett Field, CA, December 1987.

The Telescience Testbed Pilot Program is an innovative activity involving fifteen universities in user-oriented rapid-prototyping testbeds to develop the requirements and technologies appropriate to the information system of the Space Station era. The Telescience Testbed Pilot Program is required to issue progress reports to NASA Headquarters on a quarterly basis. This is the second quarterly report, covering the period September 1, 1987 through November 30, 1987.

Gallagher, Maria L. and Barry M. Leiner, *Telescience Testbed Pilot Program Third Quarterly Report*, RIACS TR 88.8, 77 pp., RIACS/USRA, Moffett Field, CA, March 1988.

The Telescience Testbed Pilot Program is required to issue progress reports to NASA Headquarters on a quarterly basis. This is the third quarterly report, covering the period December 1, 1987 through February 29, 1988.

Hack, B., *Man to Machine, Machine to Machine and Machine to Instrument Interfaces for Teleoperation of a Fluid Handling Laboratory*, Technical Report TSL-014/88, Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ, June 1988.

The purpose of this thesis is the design and description of the software necessary for teleoperation of a remotely operated fluid handling laboratory. It does not include the implementation of this software. The laboratory for which it is designed is currently being developed at the University of Arizona, and is intended to be a small scale model of the fluid handling laboratory which will be aboard Space Station. The designed software includes a man/machine interface, a machine/machine interface, and a machine/instrument interface. The man/machine interface is graphical in nature, menu driven, and consists of high level commands which are independent of the devices in the laboratory. The machine/machine interface is also device independent. It consists of intermediary commands and maps the commands of the man/machine interface to low level, device dependent, commands and programs of the machine/instrument interface. Although the software is primarily designed for the model fluid handling laboratory, the needs and requirements of the operation of a similar laboratory aboard Space Station have been considered.

Kaplan, George C., "EUVE Contributions to Telescience," *EUVE Technical Bulletin*, no. 4, p. 2, Space Sciences Laboratory, UC Berkeley, Berkeley, CA, September 1987.

Brief Overview of UC Berkeley's telescience experiments for the TTPP.

Koch, David, Terry Herter, John Stauffer, and Erick Young, *Telescience Applied to the Space Infrared Telescope Facility*, 8 pp., Smithsonian Astrophysical Observatory (Koch); Department of Astronomy, Cornell University (Herter); NASA/Ames Research Center (Stauffer); Steward Observatory, University of Arizona (Young), September 1987.

In the future, the approach to the conduct of scientific space missions will be substantially different from the approach that has been used in the past. A more distributed approach will be taken with the scientists conducting operations and analysis, remotely from their home institutions, making major use of standardized software and compatible hardware. Key to this approach have been the rapid adoption of the use of local and wide area networks, the use of standardized software tools and the plethora of powerful workstations. These developments will be applied to the Space Infrared Telescope Facility project in the space station era. A number of telescience testbed activities are being undertaken to develop experience and to determine the applicability of telescience methods.

Leiner, Barry M., *Telescience Testbed Pilot Program*, RIACS TR 87.12, 42 pp., RIACS/USRA, Moffett Field, CA, May 1987.

The Telescience Testbed Pilot Program is an innovative activity to address a number of critical issues in the conduct of science in the Space Station era. Several scientific experiments using advanced information processing and communications technologies will be carried out and the results evaluated to determine the requirements and their priorities. This will provide quantitative evidence as to the relative importance of different functions in the SSIS and their required performance. Furthermore, it will allow a set of scientific users to gain experience with advanced technologies and their application to science. This report is based on the proposal from USRA to NASA for the establishment of the Telescience Testbed Pilot Program. It describes the motivation for the program, the structure of the effort, and several strawman scientific experiments that constitute the heart of the activity.

Leiner, Barry M. and James R. Weiss, *Telescience Testbedding: An Implementation Approach*, RIACS TR 88.2, 9 pp., RIACS/USRA (Leiner) & NASA/HQS (Weiss), Moffett Field, CA, February 1988.

Telescience is the term used to describe a concept being developed by NASA's Office of Space Science and Applications (OSSA) under the Science and Applications Information System (SAIS) Program. This concept focuses on the development of an ability for all OSSA users to be remotely interactive with all provided information system services for the Space Station era. This concept includes access to services provided by both flight and ground components of the system and emphasizes the accommodation of users from their home institutions. Key to the development of the Telescience capability is an implementation approach called rapid-prototype testbedding. This testbedding is used to validate the concept and test the applicability of emerging technologies and operational methodologies. Testbedding will be used to first determine the feasibility of an idea and the applicability to real science usage. Once a concept is deemed viable, it will be integrated into the operational system for real time support. It is believed that this approach will greatly decrease the expense of implementing the eventual system and will enhance the resultant capabilities of the delivered systems.

Leiner, Barry M., *Telescience Testbed Pilot Program Interim Report*, RIACS TR 88.6, 16 pp., RIACS/USRA, Moffett Field, CA, February 1988.

The Universities Space Research Association (USRA), under sponsorship from the NASA Office of Space Science and Applications, is conducting a Telescience Testbed Pilot Program. Fifteen universities, under subcontract to USRA, are conducting a variety of scientific experiments using advanced technology to determine the requirements and evaluate trade-offs for the information system of the space station era. This report represents an interim set of recommendations based on the experiences of the first six months of the pilot program.

Marchant, Will, Carl A. Dobson, Supriya Chakrabarti, and Roger F. Malina, "Telescience -Concepts and Contributions to the Extreme Ultraviolet Explorer Mission," *SPIE Proceedings*, vol. 851, p. 173, Astronomy Dept. & Space Sciences Laboratory, UC Berkeley, Berkeley, CA, November 1987. Also available in Space Astrophysics Group Contribution Number 315.

A goal of the telescience concept is to allow scientists to use remotely located instruments as they would in their laboratory. Another goal is to increase reliability and scientific return of these instruments. In this paper we discuss the role of transparent software tools in development, integration, and postlaunch environments to achieve hands on access to the instrument. The use of transparent tools helps us to reduce the parallel development of capability and to assure that valuable pre-launch experience is not lost in the operations phase. We also discuss the use of simulation as a rapid prototyping technique. Rapid prototyping provides a cost-effective means of using an iterative approach to instrument design. By allowing inexpensive production of testbeds, scientists can quickly tune the instrument to produce the desired scientific data. Using portions of the Extreme Ultraviolet Explorer (EUVE) system, we examine some of the results of preliminary tests in the use of simulation and transparent tools. Additionally, we discuss our efforts to upgrade our software "EUVE electronics" simulator to emulate a full instrument, and give the pros and cons of the simulation facilities we have developed.

Pan, Ya-Dung, *Teleoperation of Mechanical Manipulators Aboard the U.S. Space Station*, Technical Report TSL-002/87, 74 pp., Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ, December 1987.

This study presents a new analytical controller design strategy for the teleoperation of mechanical manipulators aboard the U.S. space station. This controller design strategy emphasizes on the stability of a closed-loop control system involving time delay. Simplified dynamic equations of the Stanford arm are considered as the manipulator model. A local linearizing and decoupling control algorithm is

applied to linearize and decouple the dynamic equations. Once the linear form of the manipulator is obtained, a model prediction control loop is constructed and implemented as a digital controller to provide the predictive states information, and a particular model reduction method is applied to yield a reduced-order digital controller. This reduced-order digital controller is a highly self-tuned controller which can control the closed-loop system with time delay by following a specified performance.

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Raize, Efraim, *Computer Interface for Electrophoresis Apparatus*, Technical Report TSL-011/88, 28 pp., Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ, May 1988. The author is a visiting scholar at the University of Arizona.

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Raize, Efraim, *Syringe Driver Assembly for Automatic Fluid Handling Laboratory*, Technical Report TSL-012/88, 17 pp., Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ, May 1988. The author is a visiting scholar at the University of Arizona.

This report describes the design and implementation of a driver assembly for an automated fluid handling laboratory.

Schmerling, Erwin, "The Interaction of Users with Instruments and Databases in Space," *Information Systems Newsletter*, pp. 12-18, NASA Headquarters, January 1988.

This article discusses the Telescience Testbed Pilot Program's objectives, planned contributions and defines the term Telescience.

Schooley, Larry C. and Francois Cellier, *Telescience Testbed Pilot Program Quarterly Report*, Technical Report TSL-003/87, 16 pp., Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ, December 1987.

First quarterly report for the University of Arizona's Telescience Testbed Pilot Program.

Schooley, Larry C., Richard A. Bienz, and Francois Cellier, *Basic Research in Telescience Testbed Program Final Report: NASA Grant NAGW-1073*, Technical Report TSL-005/88, Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ, January 1988.

Final report for NASA grant NAGW-1073.

Schooley, Larry C., Don G. Schultz, and Francois Cellier, *University of Arizona Presentation, Second Telescience Testbed Pilot Program Meeting*, Technical Report TSL-007/88, 50 pp., Electrical and Computer Engineering, University of Arizona, Tucson, AZ, March 1988.

The set of transparencies presented by the University of Arizona at the second TTPP meeting held in Boulder, CO on March 7-9, 1988.

Schooley, Larry C. and Francois Cellier, *Telescience Testbed Pilot Program Quarterly Report For Winter 1987-88*, Technical Report TSL-008/88, 15 pp., Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ, March 1988.

Second quarterly report for the University of Arizona's Telescience Testbed Pilot Program.

Schooley, Larry C. and Francois Cellier, *Telescience Testbed Pilot Program Quarterly Report for Spring 1988*, Technical Report TSL-013/88, 10 pp., Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ, June 1988.

This is the third quarterly report for the astrometric telescope, remote fluid handling, and technology development projects at the University of Arizona. It does not include the UA involvement in the SIRTf project.

Starks, Scott, David Elizandro, Barry M. Leiner, and Michael Wiskerchen, "Computer Networks for Remote Laboratories in Physics and Engineering," 1988 Annual Conference of the American Society for Engineering Education, June 1988, (also available as RIACS TR 88.13, 7 pp., April 1988).

As we embark on a new era in engineering education, we must exploit technological advances which offer opportunities for improving the educational process. One area of technology which offers opportunities for enhancing the manner in which research is conducted and ultimately affects scientific and engineering education is computer networks. As computer hardware has become less expensive, more numerous and more capable, individuals and organizations have developed a keen interest in connecting them together in order to form networks. This in turn has had an impact on the manner in which laboratory research is conducted. This paper addresses a relatively new approach to scientific research, telescience, which is the conduct of scientific operations in locations remote from the site of central experimental activity. A testbed based on the concepts of telescience is being developed to ultimately enable scientific researchers on earth to conduct experiments onboard the Space Station. This system along with background materials are discussed in this paper.